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UTILITY PATENT APPLICATION TRANSMITTAL
(Large Entity)

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Docket No.
A-6388

Total Pages in this Submission
71

TO THE ASSISTANT COMMISSIONER FOR PATENTS
Box Patent Application
Washington, D.C. 20231

Transmitted herewith for filing under 35 U.S.C. 111(a) and 37 C.F.R. 1.53(b) is a new utility patent application for an invention entitled:

OPTICAL SYMBOLOGIES IMAGER

and invented by:

Jay Dowling and Howard Stern

If a CONTINUATION APPLICATION, *check appropriate box and supply the requisite information:*

☐ **Continuation** ☐ **Divisional** ☐ **Continuation-in-part (CIP)** of prior application No.: ______

Which is a:

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Enclosed are:

Application Elements

1. ☒ Filing fee as calculated and transmitted as described below
2. ☒ Specification having 19 pages and including the following:
   a. ☒ Descriptive Title of the Invention
   b. ☒ Cross References to Related Applications *(if applicable)*
   c. ☐ Statement Regarding Federally-sponsored Research/Development *(if applicable)*
   d. ☐ Reference to Microfiche Appendix *(if applicable)*
   e. ☒ Background of the Invention
   f. ☒ Brief Summary of the Invention
   g. ☒ Brief Description of the Drawings *(if drawings filed)*
   h. ☒ Detailed Description
   i. ☒ Claim(s) as Classified Below
   j. ☒ Abstract of the Disclosure

UTILITY PATENT APPLICATION TRANSMITTAL (Large Entity) *(Only for new nonprovisional applications under 37 CFR 1.53(b))*	Docket No. A-6388
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Application Elements (Continued)

3. ☒ Drawing(s) *(when necessary as prescribed by 35 USC 113)*
   a. ☐ Formal Number of Sheets ______
   b. ☒ Informal Number of Sheets 41
4. ☐ Oath or Declaration
   a. ☐ Newly executed *(original or copy)* ☐ Unexecuted
   b. ☐ Copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional application only)*
   c. ☐ With Power of Attorney ☐ Without Power of Attorney
   d. ☐ DELETION OF INVENTOR(S)
   Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. 1.63(d)(2) and 1.33(b).
5. ☐ Incorporation By Reference *(usable if Box 4b is checked)*
   The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. ☐ Computer Program in Microfiche *(Appendix)*
7. ☐ Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all must be included)*
   a. ☐ Paper Copy
   b. ☐ Computer Readable Copy *(identical to computer copy)*
   c. ☐ Statement Verifying Identical Paper and Computer Readable Copy

Accompanying Application Parts

8. ☐ Assignment Papers *(cover sheet & document(s))*
9. ☐ 37 CFR 3.73(B) Statement *(when there is an assignee)*
10. ☐ English Translation Document *(if applicable)*
11. ☐ Information Disclosure Statement/PTO-1449 ☐ Copies of IDS Citations
12. ☐ Preliminary Amendment
13. ☒ Acknowledgment postcard
14. ☐ Certificate of Mailing
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P01ULRG/REV04

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Accompanying Application Parts (Continued)

15. ☐ Certified Copy of Priority Document(s) *(if foreign priority is claimed)*

16. ☐ Additional Enclosures *(please identify below)*:

Fee Calculation and Transmittal

CLAIMS AS FILED

For	#Filed	#Allowed	#Extra	Rate	Fee
Total Claims	41	- 20 =	21	x $22.00	$462.00
Indep. Claims	5	- 3 =	2	x $82.00	$164.00
Multiple Dependent Claims (check if applicable) ☐					$0.00
				BASIC FEE	$790.00
OTHER FEE *(specify purpose)*					$0.00
				TOTAL FILING FEE	$1,416.00

☒ A check in the amount of **$1,416.00** to cover the filing fee is enclosed.

☒ The Commissioner is hereby authorized to charge and credit Deposit Account No. **08-2455** as described below. A duplicate copy of this sheet is enclosed.

- ☐ Charge the amount of as filing fee.
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- ☒ Charge any additional filing fees required under 37 C.F.R. 1.16 and 1.17.
- ☐ Charge the issue fee set in 37 C.F.R. 1.18 at the mailing of the Notice of Allowance, pursuant to 37 C.F.R. 1.311(b).

Douglas W. Robinson
Signature

Dated: 9/11/98

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P01ULRG/REV04

OPTICAL SYMBOLOGIES IMAGER

CROSS REFERENCE TO RELATED APPLICATIONS

This application is related to copending U.S. Patent Application Serial No. (Symbology Imager System) and United States Application No. (Bar code Illumination system) the entire disclosures of which are incorporated herein by reference. Further, International Application Serial No. WO 97/42756 filed on May 6, 1996, for a Smart Progressive-Scan Charge Coupled Device Camera, and which was filed by CIMatrix, one of the co-applicant's of the present application is also incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an imager for reading optical symbologies such as traditional bar codes and 2D symbologies. More particularly, the present invention relates to a hand-held optical code imager which quickly and easily adjusts illumination and focus and has an preferred operating range of approximately 1.5 to 16 inches, however, the imager may have an operating range with both lower and higher limits, and still fall within the intended scope of the present application.

2. Description of the Prior Art

The use of bar codes has proliferated to the point where they are used in almost every industry to provide machine readable information about an item or product and to help track such items. Numerous different symbologies have been developed, such as one dimensional linear codes and 2D codes, such as Data Matrix. Typical linear codes comprise a series of parallel lines of varying thickness and spacing which are arranged in a linear configuration to represent a digital code containing information relating to the object. The use of bar codes has expanded due to the fact that the imaging and tracking process eliminates human error and can be performed quickly.

The amount of information a bar code can contain is dependent upon the size of the markings employed in the bar code, which determines the density of the code. Linear bar codes such as UPC codes, are only recorded in one dimension. On the other hand, 2D symbologies are encoded in two dimensions to contain greater information density.

In a typical reading process, a spot of light from a laser is projected and swept across the code, and the reflected light is sensed by a photosensitive element. In conventional imagers, lasers are used as the source illumination. Scanners may be either installed in a fixed location or portable hand-held units.

Hand-held scanners must be designed to operate in situations where the number of varying factors is greater than for fixed scanners. For instance, the distance between the scanner and the bar code, the amount of illumination, the focusing of the scanner, the orientation of the scanner relative to the bar code, and the angle of the scanner relative to the bar code are all factors which must be considered for the scanner to operate correctly. For instance, U.S. Patent No. 5,296,690 to Chandler et al. discloses a system for locating and determining the orientation of bar codes in a two-dimensional image. The Chandler et al. patent is primarily concerned with making sure that the scan of the bar code is performed correctly with regard to the orientation of the scanner and the bar code.

Some hand-held scanning devices have a wand-like configuration where the device is intended to make contact with the code as it is swept across the code. Such a wand eliminates the variation in the distance between the scanner and the code and therefore requires no focusing.

Two-dimensional arrays such as CCD arrays have been used to create the image of the bar code as it is scanned, but traditionally a laser and a single photodiode are used for scanning a linear bar code. A CCD having dimensions of 640 by 480 pixels provides sufficient resolution for use with VGA monitors, and is widely accepted. The video image is sensed in the CCD, which generates an analog signal representing the variation in intensity of the image, and an analog to digital converter puts the image signal into digital form for subsequent decoding. Two dimensional sensors are used with spatially oriented 2D codes.

For a non-contact hand-held scanner, it is necessary to be able to read the bar code over a reasonable distance, to provide sufficient illumination, to focus the scanner onto the bar code and perform the entire operation in a reasonable amount of time. While it may be possible to create an imager which can perform all of the desired functions, if the imager does not operate in a manner the user finds comfortable and sufficient, then the imager will not be accepted by end users and will not be commercially viable. For example, if the imager cannot perform the focusing quickly enough, then variations in the position of the scanner, due to the inability of the user to hold the imager steady, will create problems which cannot be easily overcome.

By way of example, if a scanner takes too long to perform a focusing function from the moment the user depresses a trigger, then the position of the scanner relative to the bar code may vary during the focusing operation thereby requiring yet another focusing operation. Similarly, such movement in the position of the scanner relative to the bar code will change the parameters for achieving the desired illumination.

Scanners which have been designed to read linear, or one dimensional, codes are, for the most part, incapable of scanning 2D symbologies. Linear and 2D symbologies may be provided on items by attaching a label to the item, putting the item in a container having a preprinted code, or by directly marking the product, such as by etching. Most conventional scanners may find it difficult to read symbologies which have been etched directly onto a product.

SUMMARY OF THE INVENTION

These and other deficiencies of the prior art are addressed by the present invention which is directed to a hand-held imager which is capable of reading both linear one dimensional codes and two dimensional symbologies, which can perform illuminating and focusing steps quickly and accurately so as to eliminate variation in the position of the imager relative to the code, and which can operate in an environment where the imager is preferably positioned anywhere from substantially 1.5 inches to 16 inches from the targeted code.

The hand-held imager of the present invention can perform omnidirectional coded symbology reading for both linear and two-dimensional symbologies over relatively long working distances. The imager includes an imaging system having a focusing system, an illumination system, and a two-dimensional photodetector which forms an image of the bar code. After achieving targeting of the coded symbology, the reader of the present invention adjusts illumination and then the focus between multiple different focuses, and utilizes a portion of the two-dimensional photodetector to determine the optimum focus. Upon the determination of optimum focus, the focusing system is configured at the optimum focusing configuration established in the initial focusing step, and an image is created using the entire two-dimensional photodetector.

A targeting system visually assists the user to position the reader so that the coded symbology, being targeted, is within the field of view of the reader. The reader has two types of illumination, one for symbologies which are close to the reader, and a second type of illumination for symbologies which are farther from the reader. The two-dimensional photodetector may be employed to determine the optimum illumination.

It is an object of the present invention to provide a hand-held reading device capable of reading both linear and 2D coded symbology.

Another object of the present invention is to provide a hand-held reader which can perform an imaging operation in a range between 1.5 inches and 16 inches to the coded symbology for typical hand-held use, but may have both higher and lower distance limits.

Yet another object of the present invention is to provide a hand-held reader capable of reading direct product markings in addition to coded symbology printed on labels.

Still another object of the present invention is to provide a hand-held reader which utilizes a two dimensional sensor to facilitate focusing and illumination adjustment.

Yet another object of the present invention is to provide a hand-held reader which utilizes a two dimensional sensor to facilitate focusing and illumination adjustment, where only a small portion of information received by the two dimensional sensor is used, to thereby speed processing.

Another object of the present invention is to provide a hand-held reader made from commonly available "off-the-shelf" components.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other attributes and objects of the present invention will be described with respect to the following drawings in which:

FIG. 1 is a perspective view of the reader according to the present invention;

FIG. 2 is a plan view of a typical linear type coded symbology;

FIG. 3 is a plan view of a Data Matrix symbology;

FIG. 4 is a cross-sectional view of the reader shown in Fig. 1 according to the present invention;

FIG. 5a is a perspective view of a first embodiment of a focusing disk which may be employed in the focusing system of the present invention;

FIGS. 5b and 5c are planar and cross-sectional views, respectively, of a second embodiment of a focusing disk which may be employed in the focusing system of the present invention;

FIGS. 6a - 6k are represent eleven images p1 - p11, where images p1 - p6, shown in Figs. 6a - 6f, are used in the photonics or photometric analysis, and images p6 - p11, shown in Figs. 6f - 6k, are used in the focus analysis;

FIG. 7 shows a pixel plot of line 235 of a CCD for the values between 128 and 508, in the horizontal location, for images p1, p6, and p11, shown in Figs. 6a, 6f and 6k;

FIGS. 8a - 8h show Table A, containing data from which the pixel plots of Fig. 7 are derived;

FIG. 9 is an edge histogram for images p1 - p6, shown in Figs. 6a - 6f;

FIGS. 10a - 10e show Table B which contains the population for each peak-to-peak value of each image p1 - p6, and illustrated in Fig. 9;

FIG. 11 is a table showing the entropy score, maximum pixel value and minimum pixel value for each image p1 - p6;

FIGS. 12a and 12b are frequency histograms for images p6 - p11, shown in Figs. 6f - 6k, with Fig. 12b being an enlargement of a portion of Fig. 12a;

FIGS. 13a - 13e show Table C which contains the delta peak value of each image p6 - p11;

FIG. 14 is a chart showing the entropy score, maximum pixel value and minimum pixel value for each image p6 - p11; and

FIG. 15 is a block diagram of the imager according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The hand-held reader 10 shown in Fig. 1 is capable of reading coded symbologies omnidirectionally, and producing decoded data. The scanning device 10 is self-sufficient and does not require an external power source, except for host power provided through an interface cable 14. The scanner 10 can read both linear bar codes 40, as shown in Fig. 2, and matrix or 2D coded symbologies 54 as shown in Fig. 3.

The linear or 2D coded symbologies are standard symbologies well known in the art, and the decoding of them is similarly well known. However, unlike conventional scanners, the reader 10 of the present invention can read both types of symbologies, can operate over a wide range of distances, 1.5 to 16 inches, and is held-held. To achieve these results, the reader 10, upon activation by the user, must be able to target the coded symbology, determine the optimum illumination, determine the optimum focus, and make an image of the targeted coded symbology in an extremely short period of time in order to eliminate possible degrading variations.

For example as the user holds the reader 10 relative to a linear bar code 40 or a 2D coded symbology 54, the reader can move relative to the code thereby changing the focus, illumination and angle of the scanner relative to the code. By performing the entire image capture function as quickly as possible, from the moment targeting is achieved, such variables are minimized. How such rapid image focusing, illumination and capture are performed will be described in detail below.

The reader 10 includes an ergonomic housing 12 designed to fit comfortably in a user's hand. The reader 10 decodes the data, and forwards the decoded data to a computing device platform, such as a PDT, PLC or PC, which performs information

gathering as one of its functions. A switch or trigger 15 protrudes through the top of the housing 12 for activation by the user's finger. Lights 18 and 20 are provided on the top of the housing 12 and indicate the active status and successful imaging of the coded symbology, respectively. Audible signals may also be provided.

The hand-held imager 10 utilizes an aiming device to locate the target symbologies in the field of view (FOV). The method of targeting is designed to minimize power consumption. A programmable two-phase trigger is used to acquire the target symbology.

A window 22 having a clear aperture section 24 is provided on the front of the housing 12. A targeting line 32 is produced by a light source in the hand-held imager 10 and is projected onto the targeted coded symbology to ensure that the coded symbology 40 or 54 is within the field of view of the imager 10. The targeting line 32 is preferably a color, such as red, which is discernable from the ambient light sources.

In operation, the user presses the trigger 15 to a first position thereby causing the projection of the targeting line 32 onto the coded symbology. The targeting line 32 is then used to position the imager 10 and the coded symbology relative to one another. The imager 10 then adjusts the illuminating light if necessary, and determines the correct focus. The light 18 is illuminated to indicate to the user that imaging is underway. Upon completion of the imaging process the light 20 turns on to provide the user with an indication of successful scanning.

Referring to Figs. 2 and 3, a linear code 40 and Data Matrix code 54, respectively, are shown. Typical 2D or Data Matrix symbologies are smaller than linear codes and may be

etched directed onto the product. The information is typically encoded in feature sizes of 5, 7.5, or 10 mils. As a result, the imager 10 needs to be much closer when reading 2D symbologies 54 than for linear codes 40.

The imager 10 is shown in cross-section in Fig. 4, where the optical system 80 is illustrated as including objective taking lens 92 and focusing disk 94. The disk is driven rotational at 600 RPM about axis 91 by the motor 96. The rotational axis 91 is offset from the optical axis O_A of the imaging system 80. A dark field illuminator 82 having multiple light emitting elements 98, such as LEDs, which illuminate rearwardly onto a non-transparent wall, which then provides diffuse light to the window 22. A bright field illuminator 84 is provided with multiple light emitting elements 100 for radiating forward directly through the window 22. Dark field illumination is provided for direct product marking (low contrast), while bright field illumination is used primarily for high contrast label marks.

Built-in bright field and dark field illumination are provided to achieve proper contrast for reading the symbologies on direct product marked parts at close-in distances. Only bright field illumination is used at greater working distances. The details of the illumination system are set forth in co-pending commonly owned patent application serial no. (######) filed on (date).

A key aspect of the present invention is the CCD detector 93, positioned along the optical axis $O_{A.}$ The CCD detector 93 is rectangular and has a VGA pixel density. In the preferred embodiment, the CCD detector 93 is an interline 659 x 494 progressive scan, monochromatic CCD, which may be manufactured by Panasonic Corporation, model #MN37761AE, or a 659 x 494 pixel CCD manufactured by Sony Corporation, model # ICX084AL.

Both of the foregoing CCD's provide 640 x 480 resolution commonly used in VGA monitors. While the preferred embodiment illustrated herein utilizes a CCD, other array detectors such as CMOS, or other sensors may be used. Furthermore, the CCD need not be limited to 640 by 480 and may have other sizes.

The hand-held imager 10 can decode multiple symbologies on any background, including etched metal and printed ink jet. The paramount reading capability for use on surfaces that are direct product marked is the Data Matrix symbology.

A first embodiment of the focusing disk 94, shown in cross-section in Fig. 4, is shown in greater detail in Fig. 5a. The disk 94 has a series of different thickness optical positions 132. The thickness of the optical positions 132 is varied to focus the objective lens 92 onto the CCD detector 93 during image capture. The illustrated embodiment shows twelve optical positions 132 which thereby provide twelve potential focus ranges. A positional encoding strip 134 is provided on the disk 94 so that the position of the disk can be tracked.

Referring to Figs. 5b and 5c, planar and cross-sectional views of a second embodiment of the focusing disk 94 is shown. The second embodiment has eight optical positions 132 and further includes an outer circumferential wall 136 which provides additional structural support.

The CCD detector 93 is utilized to determine which optical plate 132, and therefore which focusing zone, is appropriate for a particular coded symbology scan. As the disk 94 is rotated, the illuminating light is reflected back through the objective lens 92 through each of the optical positions 132 and onto the CCD detector 93. In order to minimize the time it takes to focus the imager 10, only a fraction of the pixels of

the CCD detector 93 are employed in the determination of the optimum optical plate, and thereby the focused optical plate.

From start up, the imager 10 produces target illumination, then takes approximately 25 to 30 milliseconds to reach the rotational speed of 600 RPM. The CCD then powers up and then resets. Multiple, up to five, images are taken for photometry, and multiple images are taken for focusing. Each image requires exposure time and shift out time, which is in the range of, but no greater than 5.5 mS. After the optimum optical plate is repositioned in the optical path the CCD detector must capture and shift out the entire image in about 31.4 milliseconds. The total time for the entire operation is therefore less than half a second, which is sufficient to minimize the variable factors discussed previously.

The aforementioned variations are more detrimental to photometry than to focus analysis. In order to minimize the variations, the present invention employs a number of techniques to accelerate the operation. First, the imager operates in a "fast mode." A small size slice of an image, 384 by 10, is utilized, 384 being over 60% of the image width, and 10 scan lines is more than two times the minimum cell size requirement (4 pixels). This ensures than a transition will be encountered in the image slice, while having as small a size a feasible. The search for the proper exposure time uses seven images, but the use of only five images is contemplated, which will require no more than 30 mS. The optical disk 94 can be separated into two groups of optical positions 132, for Dark field and Bright Field images.

The maximum time to decode a printed label is 350 milliseconds, while the maximum time to decode a direct product marked code is 400 milliseconds. The foregoing times include the time, from the trigger is activated, to illuminate, focus,

acquire the image, decode the symbology, and output the decoded data.

If all 325,546 pixels of the CCD detector 93 were used for each optical plate 132 of the focusing disk 94, the image capture procedure would take far too long. To minimize the time required to obtain data for each optical plate 132, only a portion of the CCD detector 93 is used. In operation, the CCD detector 93 generates image data as 494 lines, one line at a time, each line being 659 pixels long. The first 246 lines, instead of being digitized which would require significant time, are "dumped." Furthermore, to accelerate the process, the speed at which the data is sent through the CCD is much faster than the speed used for normal image capture. Since the information contained in the first 246 lines is not important to the focusing steps, the degradation of such information, due to the accelerated reception, is not a detriment.

The next ten lines, lines 247-256 are utilized in the analysis described below, and then the CCD detector 93 is reset, never reading lines 257-494. In this manner, the focusing time is more than halved.

Referring to Fig. 15, a block diagram of the imager 10 of the present invention is illustrated. The CPU 200 connects to the flash memory 202 and DRAM 204, which together form the computing engine for the imager 10. The CPU 200 further connects to the serial interfaces 206, which in turn is connected to the power supply 210. A microcontroller 212 is connected by serial link to the CPU 200, and in turn is connected to the power supply 210, switches 214, motor 216 and illumination drivers 218. The Illumination drivers 218 are connected to the Bright Field and Dark Field and Targeting Illumination, shown as Illumination 224 in Fig. 15. An FPGA 220 is connected to the CPU 200, the flash memory 202, DRAM 204, illumination drivers 218 and CCD 222. The

FPGA 220 controls the CCD and the Illumination 224. The FPGA 220 and microcontroller 212 control the targeting. The Motor 216 drives the focusing disk 94.

In order to evaluate the image data for each optical plate 132, the ten middle lines of data need to be analyzed. The transitions between light and dark areas of the code are critical for such analysis. Furthermore, it is important to note that in the determination of which optical plate provides the best focus and illumination, the quality of the images relative to one another is what is important, not the absolute image quality. The imager 10 is designed to achieve correct decoding of the coded symbology targeted with the minimum necessary focusing, not perfect focusing which would require considerably more time and/or complexity.

As an example we will traverse a scan line from left to right. For the examples in figures 7-14 we used a minimum peak to peak value of 12. This means that a relative white pixel must be greater than a relative black pixel by a magnitude of 12 for it to be considered a white pixel relative to that black pixel, but other values may be used depending on the application. We will first look for a local minimum. We choose a new minimum when the current pixel is less than the previous minimum. We stop looking for a minimum and start looking for a maximum when we find a pixel with a value greater than or equal to the minimum pixel plus 12. We then continue looking for a maximum until we find a pixel that is less than or equal to the current maximum minus 12. When this occurs we have a local minimum, a local maximum, the magnitude of the difference and the number of pixels between the minimum and maximum points. The magnitude of the difference or peak to peak value is used as the index to the bin number of the edge histogram that should be incremented by one. The number of pixels between the peaks is used as the index to the bin number of the frequency histogram that should be

incremented by one. This sequence is repeated for the remainder of the scan line.

Referring to Fig. 7a, point A is the first local maxima. Point B is the first local minima. Point C is an inflection recognition point, meaning you know you are done looking for a local minima because you are more than 12 above the value at point B. You can then evaluate the pair AB. For the pair AB, the frequency corresponds to $|X(A)-X(B)|$, while the peak to peak value corresponds to $|Y(A)-Y(B)|$. Point D is not a local minima because it is not at least 12 less than point C1, an inflection point between points B and D. Point E is the second local maxima, pont F is the inflection recognition point for the pair BE. Point G is the second local minima and point H is the third inflection recognition point corresponding to the pair EG. Point I is the third local maxima.

For illustrative purposes, Fig. 7 shows a pixel plot of line 235 of the CCD for the values between 128 and 508, in the horizontal location, for images p1, p6, and p11, shown in Figs. 6a, 6f and 6k. The three images are shown by three different lines, p1 is shown by the solid line, image p6 is shown by the dashed line, and image p11 is shown by the dotted line.

The data from which the pixel plots of Fig. 7 are drawn is shown in Table A, shown in Figs. 8a - 8h, and includes the values for each horizontal location within the field. From Fig. 7, it can be clearly seen that the image p6 has the best transitions.

Illumination analysis is performed by developing entropy scores for each illuminating condition. The quality or nature of the transitions (peak-to-peak) values are taken into account by this analysis. In an edge histogram the y axis is the population or number of transitions, and the x axis represents the peak-to-peak value.

Figs. 6a-6k represent eleven images p1 - p11. Images p1 - p6, shown in Figs. 6a - 6f, are used in the following photonics or photometric analysis, and images p6 - p11, shown in Figs. 6f - 6k, are used in the following focus analysis.

Referring to Fig. 9, an edge histogram is illustrated for images p1-p6, shown in Figs. 6a - 6f. Figs. 10a - 10e show Table B which contains the population for each peak-to-peak value of each image p1 - p6. The images p1 - p6 are illustrated by different shaded areas in Fig. 9. The peak-to-peak values begin at 12, since, as shown in Fig. 10a, the first population value does not occur until 12 for image p1. Similarly, Fig. 9 ends with value 118 for image p6. The remaining values up to 255 are all zeros in the example shown in Fig. 9, and therefore are not illustrated. The entropy score, maximum pixel value and minimum pixel value for each image p1 - p6 are shown in Fig. 11, with the entropy score being the total of the population values for each image. The entropy values individually have no meaning. Rather, a comparison of the entropy values with one another shows which image has the highest entropy value. Here it is image p6 with a value of 758. With reference to Fig. 9, it is clear that image p6 has the largest area under its curve, which is represented by the entropy value. From the forgoing, it can be seen that image p6 has the best illumination.

The maximum and minimum pixel values are obtained from the average of the brightest 20 and the average of the dimmest 20 values, respectively. These maximum and minimum pixel values can be used to determine if the image meets minimum criteria for usability.

The entropy score is not used by itself, and in particular when an image is over-saturated. In that instance, the signal has reduced the peak-to-peak values, and has fewer edges than an under-saturated image.

To perform the optical plate focus analysis the microprocessor concerns itself with the rate of change of energy between neighboring pixels of image data. If all transitions are plotted in a two dimensional histogram, a graph can be generated to produce a score for determining the optimum focus. The x axis represents the number of pixels between local maxima and minima, and the y axis represents the population.

Figs. 12a - 12b are frequency histograms for images p6 - p11, shown in Figs. 6f - 6k. The number of pixels between peaks are plotted on the x-axis in a range of 1 to 123. 123 is the highest value having a population, for image p6, as shown in Table C in Figs. 13a - 13e, which provides the population values for the number of pixels between peaks. Reviewing Fig. 12a, it can be clearly seen that most of the data appears in the first 25 values on the x-axis, and therefore these values are shown in the enlarged portion of the histogram shown in Fig. 12b.

A focused image has a sharp contrast between light and dark areas. An out of focus condition is represented by the loss of high frequency components. Therefore, the image with the highest population density at high frequency indicates the best focus. The data represented in Figs. 12a and 12b is shown in Table C of Figs. 13a - 13e. Unlike illumination, the determination of the optimum focus does not use the entire population. Rather, only the first seven values are used to develop the entropy scores, shown in Fig. 14. Since slow edges are represented by low frequency values, only the first seven values are needed. According to Fig. 14, image p6 has the highest entropy score of 894, indicating that it is the best focused image.

During image capture and decoding operations, the imager 10 draws approximately 200-500 milliamperes of constant power at 4.2 - 5.25 V. Where the imager 10 interfaces with a portable data terminal (PDT), 4 to 6 V is normally specified at 200-500 mA,

while the universal serial bus (USB) interface is specified at 4.2 to 5.25 volts at 100-500 mA.

Having described the preferred embodiments of the hand-held imager in accordance with the present invention, it is believed that other modifications, variations and changes will be suggested to those skilled in the art in view of the description set forth above, such as utilizing different focusing disk configurations, or other focusing configurations such as quintic lens. It is therefore to be understood that all such variations, modifications and changes are believed to fall within the scope of the invention as defined in the appended claims.

WHAT IS CLAIMED IS:

1. An optical symbology imager, comprising:

a two dimensional photodetector having an active area for capturing an image of said optical symbology;

a focusing means for providing at least two focusing zones of said optical symbology; and

a control means for controlling said focusing means and said two dimensional photodetector to determine an optimum focus state,

wherein said focusing means is controlled by said control means to provide image data to said two dimensional photodetector for each of said at least two focusing zones,

said active area of said two dimensional photodetector shifting out said image data serially, and storing a central portion of said image data in a memory in said control means,

said control means evaluating transitions between light and dark data in said central portion of said image data to produce a representative value for each of said at least two focusing zones, wherein a largest representative value indicates which of said focusing zones provides the best focus.

2. An optical symbology imager as recited in claim 1, wherein said two dimensional photodetector is a CCD.

3. An optical symbology imager as recited in claim 2, wherein said CCD disposes of a first set of multiple scan lines, and then samples said central portion.

4. An optical symbology imager as recited in claim 3, wherein said CCD has a resolution of 659 by 494 in said active area.

5. An optical symbology imager as recited in claim 1, wherein said representative value is produced by totaling a high

frequency subset of values produced from a complete set of frequency values for each of said multiple focusing zones.

6. An optical symbology imager as recited in claim 3, wherein said representative value is produced by totaling a high frequency subset of values produced from a complete set of frequency values for each of said multiple focusing zones.

7. An optical symbology imager as recited in claim 1, wherein said control means is a microprocessor.

8. An optical symbology imager as recited in claim 1, wherein said focusing means provides twelve focusing zones.

9. An optical symbology imager as recited in claim 8, wherein said focusing means comprises a focusing disk having twelve optical positions, said focusing disk being rotatable so that each of said twelve optical positions can be moved into an optical axis of said imager, said two dimensional photodetector performing image capture for each of said twelve optical positions.

10. An optical symbology imager as recited in claim 1, further comprising an illumination means for providing variable illumination of said optical symbology.

11. An optical symbology imager as recited in claim 10, wherein said two dimensional photodetector receives said image data for multiple illumination conditions, as provided by said illumination means, said control means calculates edge totals for each image and optimum illumination is determined for one of said multiple illumination states having a largest edge total.

12. An optical symbology imager, comprising

a two dimensional photodetector having an active area for capturing an image of said optical symbology;

an illumination means for providing variable illumination of said optical symbology; and

control means for controlling said illuminating means and said two dimensional photodetector to determine optimum illumination, said illumination means providing multiple illumination conditions, said two dimensional sensor receiving image data for each of said multiple illumination conditions, said control means calculating edge totals for each image data received by said two dimensional photodetector comparing said edge totals and utilizing a largest of said edge totals as an indicator of said optimum illumination.

13. An optical symbology imager as recited in claim 12 wherein said two dimensional photodetector is a CCD.

14. An optical symbology imager as recited in claim 13, wherein said CCD disposes of a first set of multiple scan lines, and then samples said central portion.

15. An optical symbology imager as recited in claim 14, wherein said CCD has a resolution of 659 by 494 in said active area.

16. An optical symbology imager as recited in claim 12, wherein said control means is a microprocessor.

17. An optical symbology imager as recited in claim 10, wherein said illumination means comprises a dark field illuminator and a bright field illuminator.

18. An optical symbology imager as recited in claim 17, wherein said dark field illuminator comprises multiple light emitting diodes facing away from said optical symbology.

19. An optical symbology imager as recited in claim 17, wherein said bright field illuminator comprises multiple light emitting elements facing said optical symbology.

20. An optical symbology imager as recited in claim 18, wherein said bright field illuminator comprises multiple light emitting elements facing said optical symbology.

21. An optical symbology imager as recited in claim 12, wherein said illumination means comprises a dark field illuminator and a bright field illuminator.

22. An optical symbology imager as recited in claim 21, wherein said dark field illuminator comprises multiple light emitting diodes facing away from said optical symbology.

23. An optical symbology imager as recited in claim 21, wherein said bright field illuminator comprises multiple light emitting elements facing said optical symbology.

24. An optical symbology imager as recited in claim 23, wherein said bright field illuminator comprises multiple light emitting elements facing said optical symbology.

25. An optical symbology imager, comprising:

a CCD having an active area with a resolution of 659 by 494;

a focusing apparatus comprising a focusing disk with multiple optical positions to provide different focal lengths, said disk being rotatable so that each of said multiple optical positions can move into an optical path of said imager,

a microprocessor for controlling said focusing apparatus and operation of said CCD, so that said CCD performs image capture for each of said multiple optical positions,

said microprocessor controlling said CCD to shift out said image data substantially serially, and

said microprocessor evaluating transitions between light and dark data in a central set of scan lines to produce a representative value for each of said multiple optical positions, wherein a largest representative value corresponds to one of said optical positions producing optimum focus.

26. An optical symbology imager as recited in claim 25, wherein said CCD disposes of a first set of multiple scan lines, and then samples a second subsequent set of scan lines from said central set of scan lines.

27. An optical symbology imager as recited in claim 25, wherein said representative value is produced by totaling a first seven to ten values from multiple values produced for each of said multiple focusing zones.

28. A method of reading an optical symbology comprising the steps of:

capturing an image of said optical symbology in an active area of a two dimensional photodetector;

providing at least two focusing zones of said optical symbology,

controlling said two dimensional photodetector to receive said image of said optical symbology for each said two focusing zones in said active area;

said active area of said two dimensional photodetector shifting out said image data substantially serially, and

evaluating transitions between light and dark data in a central set of scan lines, producing a representative value for each of said at least two focusing zones, and determine optimum focus based upon a largest of said representative values.

29. A method of reading an optical symbology as recited in claim 28, wherein said central set of lines is ten lines.

30. A method of reading an optical symbology as recited in claim 28, further comprising the step of producing said representative value by adding a first seven to ten values from a complete set of frequency values for each of said multiple focusing zones.

31. A method of reading an optical symbology as recited in claim 28, wherein said multiple focusing zones are twelve zones.

32. A method of reading an optical symbology as recited in claim 28, wherein said focusing step comprises the step of changing between said multiple focusing zones.

33. A method of reading an optical symbology comprising the steps of:

providing multiple illumination conditions of said optical symbology;

capturing an image of said optical symbology in an active area of a two dimensional photodetector for each of said multiple illumination conditions,

determining optimum illumination by calculating edge totals for each image data received by said two dimensional photodetector;

comparing said edge total for all of said multiple illumination conditions to determine a largest edge total, and

utilizing said largest edge total as an indicator of optimum illumination.

34. An optical symbology imager as recited in claim 1, wherein said optical symbology imager is hand-held.

35. An optical symbology imager as recited in claim 12, wherein said optical symbology imager is hand-held.

36. An optical symbology imager as recited in claim 25, wherein said optical symbology imager is hand-held.

37. An optical symbology imager as recited in claim 8, wherein said focusing means comprises a focusing disk having multiple optical positions, said focusing disk being rotatable so that each of said multiple optical positions can be moved into an optical axis of said imager, said two dimensional photodetector performing image capture for each of said multiple optical positions.

38. An optical symbology imager as recited in claim 15, wherein said first set of multiple scan lines is 246 lines.

39. An optical symbology imager as recited in claim 15, wherein said second set of scan lines is substantially ten lines.

40. An optical symbology imager as recited in claim 26, wherein said first set of multiple scan lines is 246 lines.

41. An optical symbology imager as recited in claim 26, wherein said second set of scan lines is substantially ten lines.

ABSTRACT OF THE DISCLOSURE

A hand-held imager which is capable of reading both linear and two dimensional symbologies, which can perform focusing and illuminating steps quickly and accurately so as to eliminate variation in the position of the imager relative to the code becoming a negative factor, in which can operate in environment where the imager is anywhere from 1.5 inches to 16 inches from the code. The imager includes an imaging system having a focusing system, an illumination system, and a two-dimensional photodetector which forms an image of the coded symbology. After achieving targeting of the coded symbology, the scanning system adjusts the focus between multiple different focuses, and utilizes a portion of the two-dimensional photodetector to determine the optimum focus. Upon the determination of optimum focus, the focusing system is returned to the focusing configuration established in the initial focusing step, and an image is created using the entire two-dimensional photodetector. Optimum illumination is determined using the same two-dimensional photodetector.

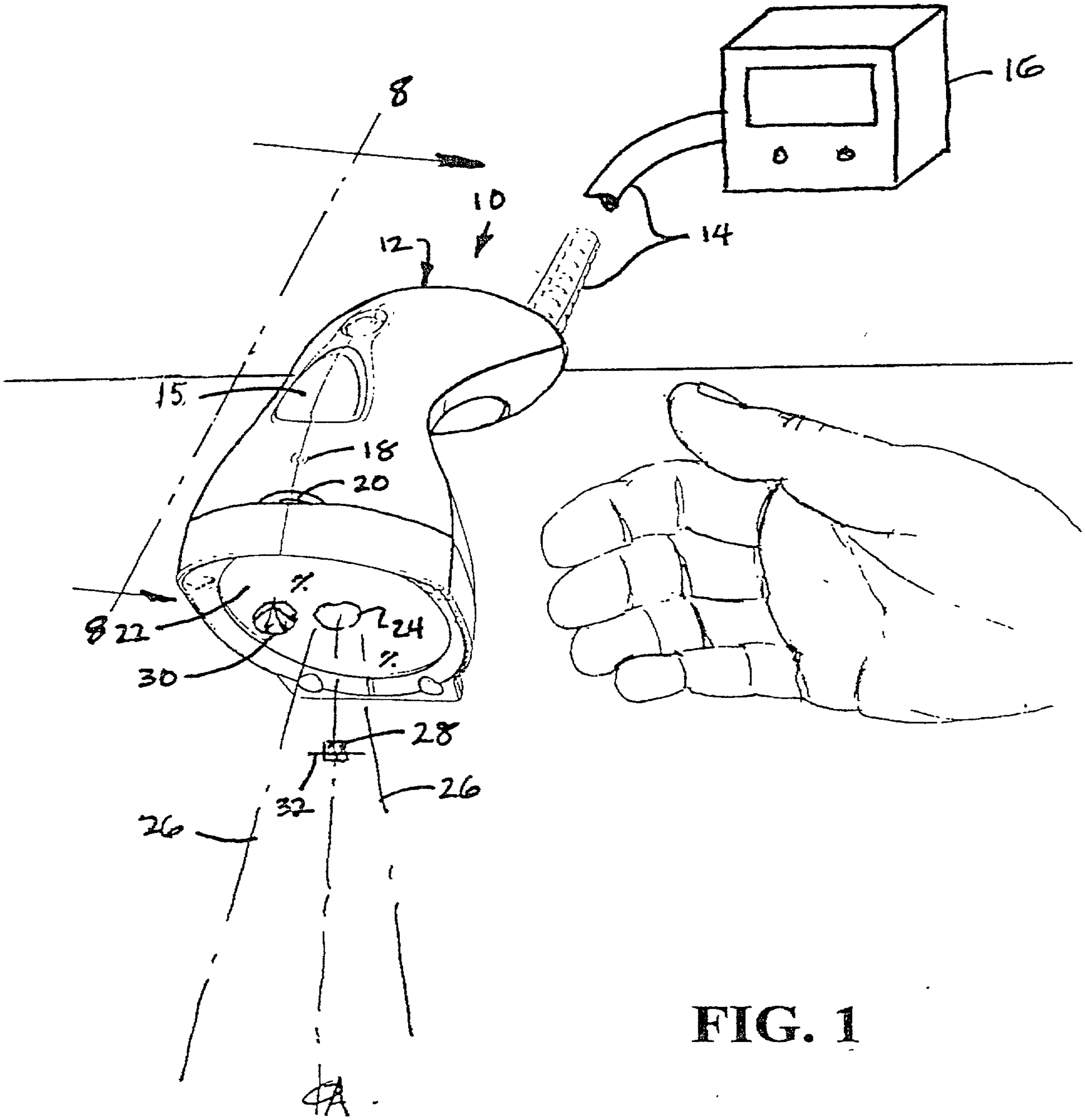


FIG. 1

54

FIG. 3

~~JDLFJLPMPRJW~~ DATA MATRIX
(matrix Code)

40

JDLFJLPMPRJW

FIG. 2

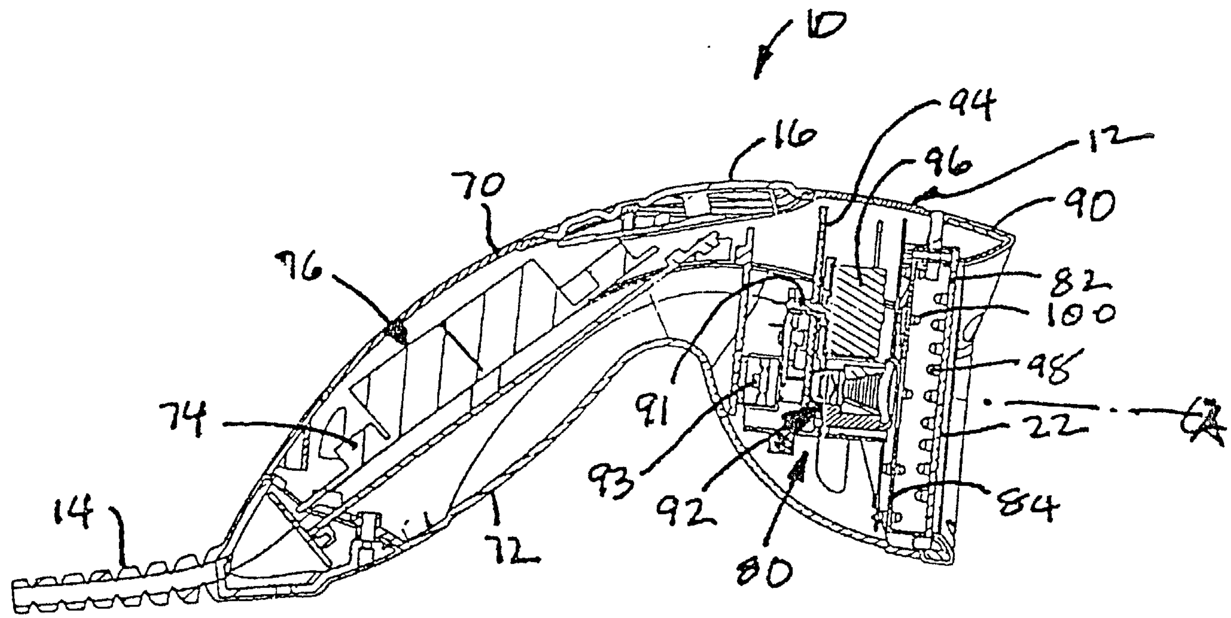


FIG. 4

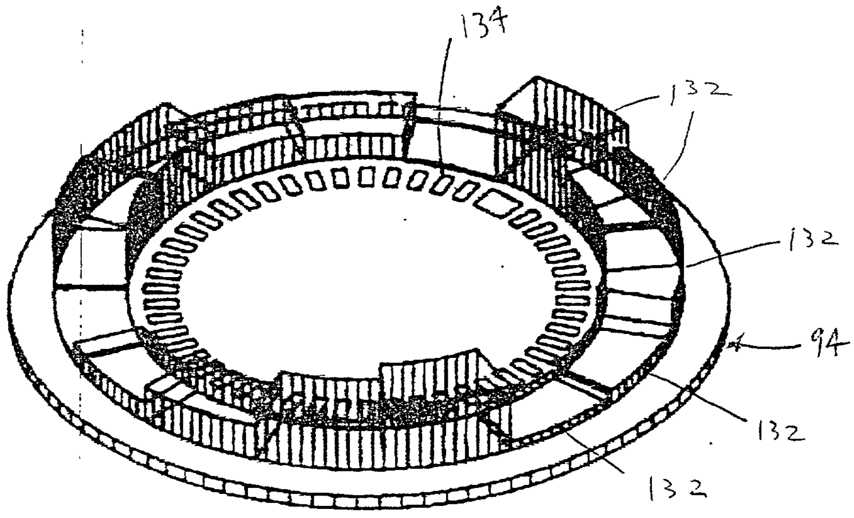


FIG. 5a

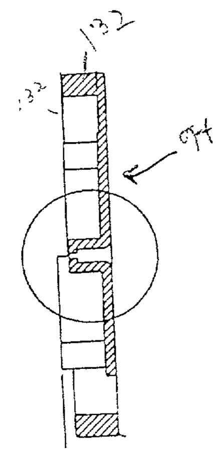


FIG. 5c

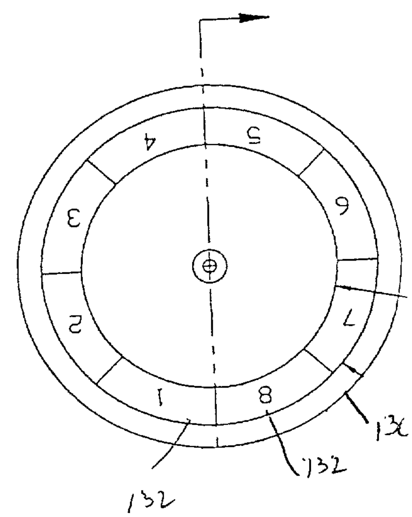


FIG. 5b

Photonics Analysis : Images p1 ~ p6
Focus Analysis: Images p6 ~ p11

P1 image

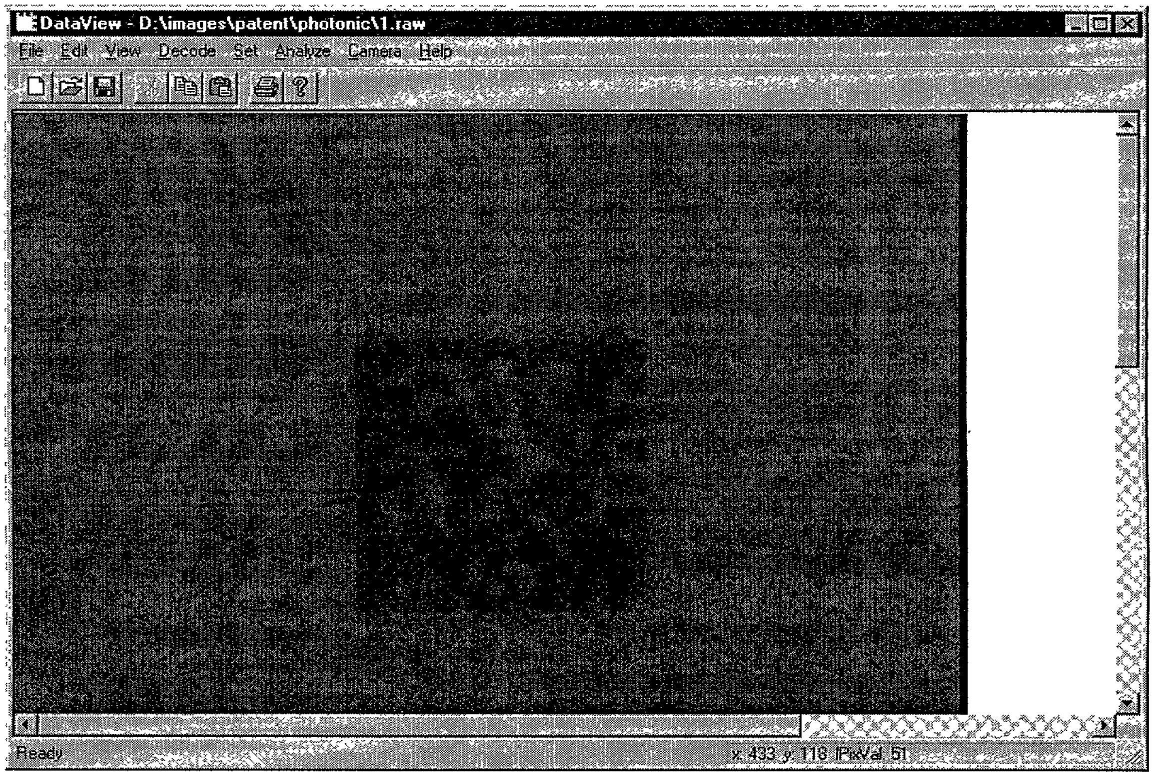


FIG. 6a

P2 image

FIG. 6b

P3 image

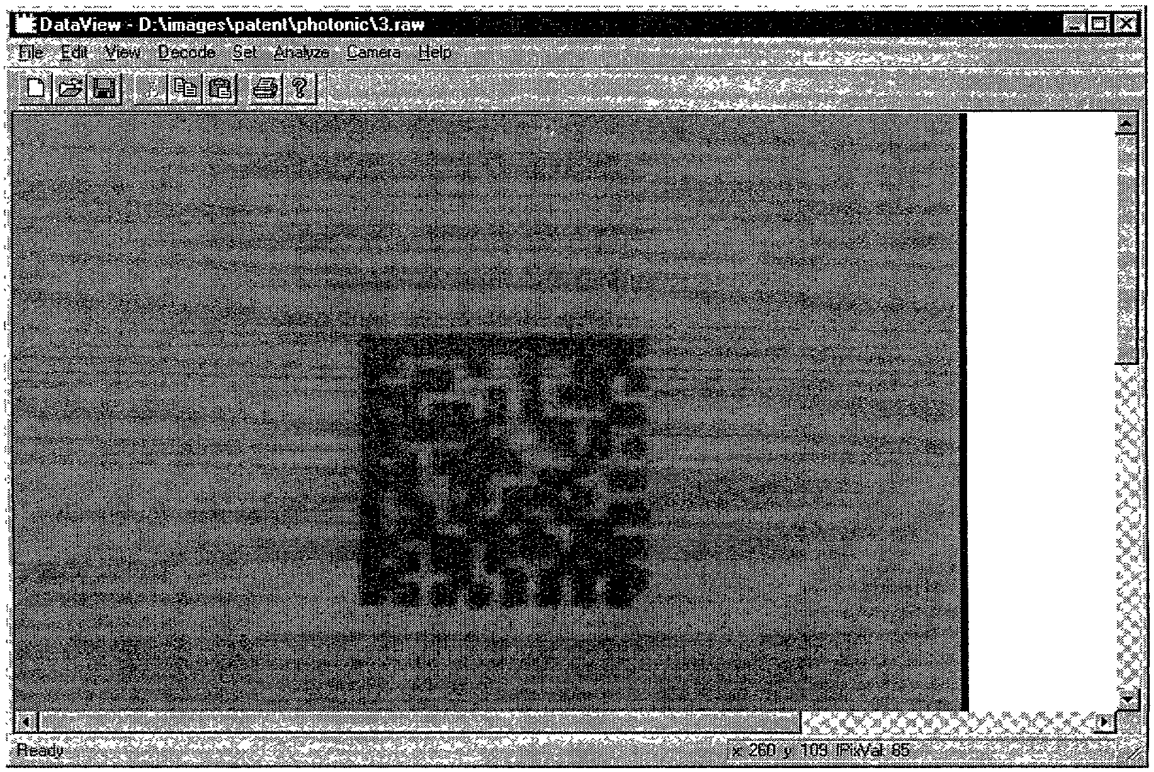


FIG. 6c

P4 image

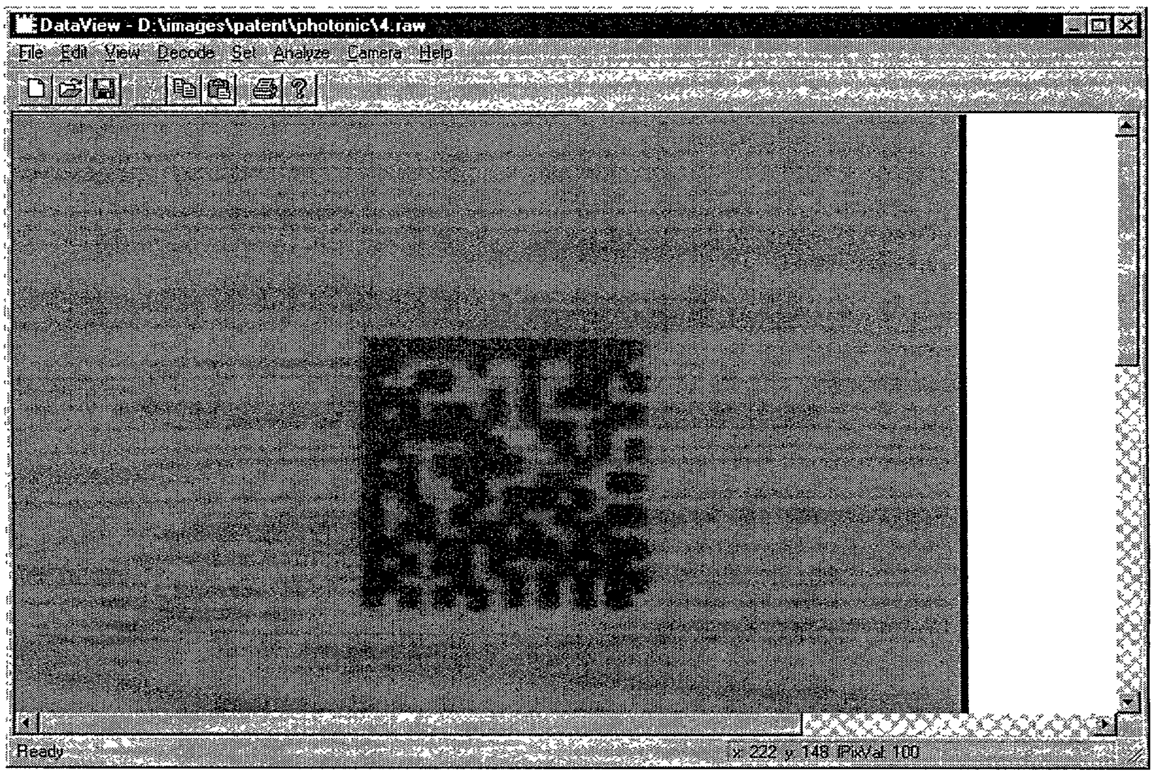


FIG. 6d

P5 image

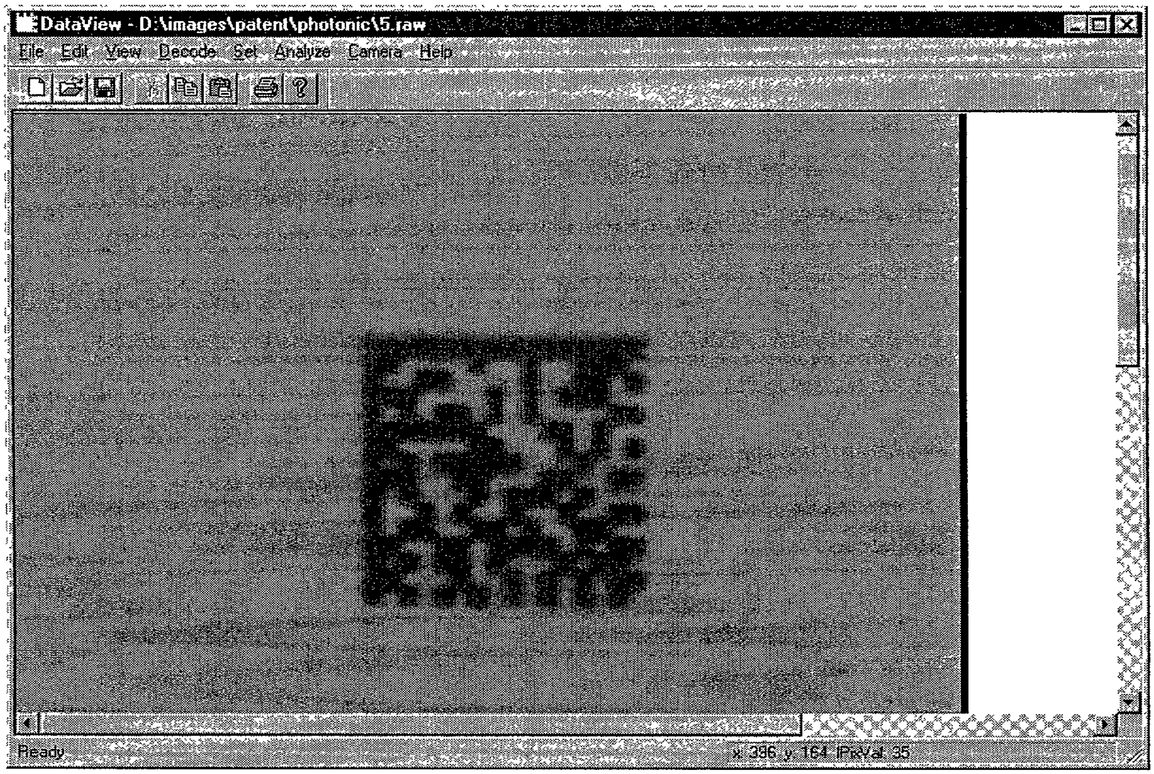


FIG. 6e

P6 image

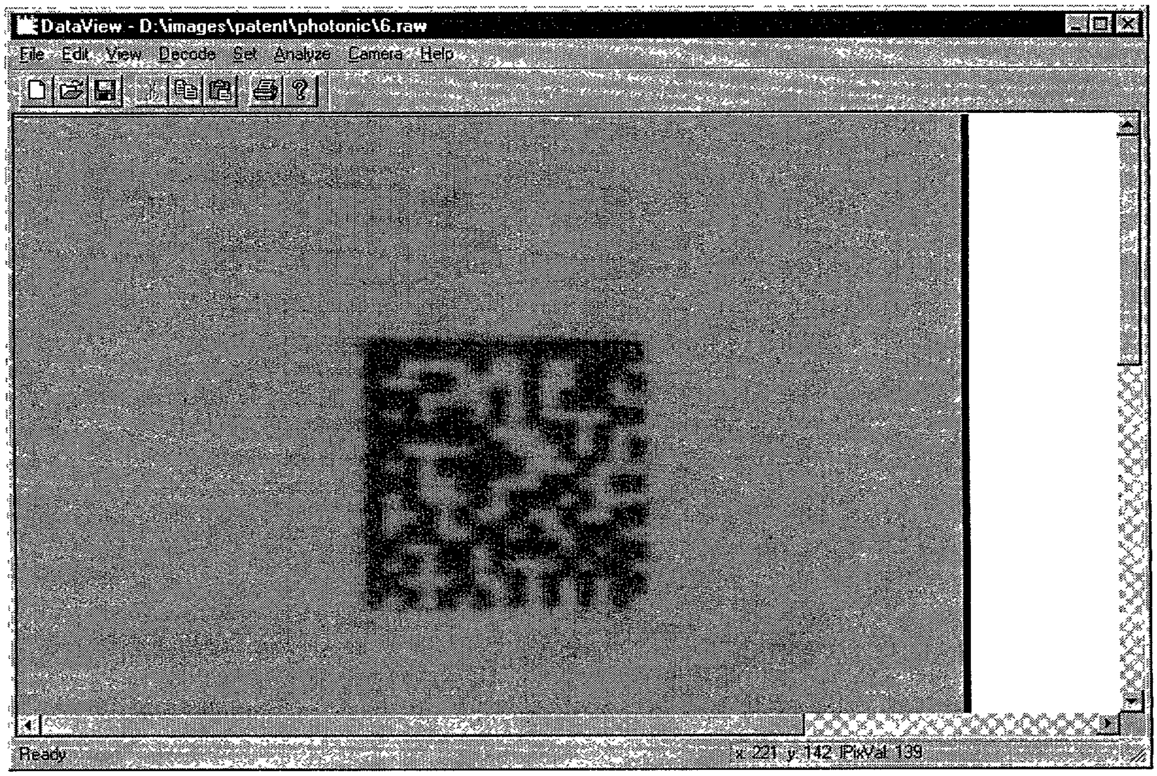


FIG. 6f

P7 image

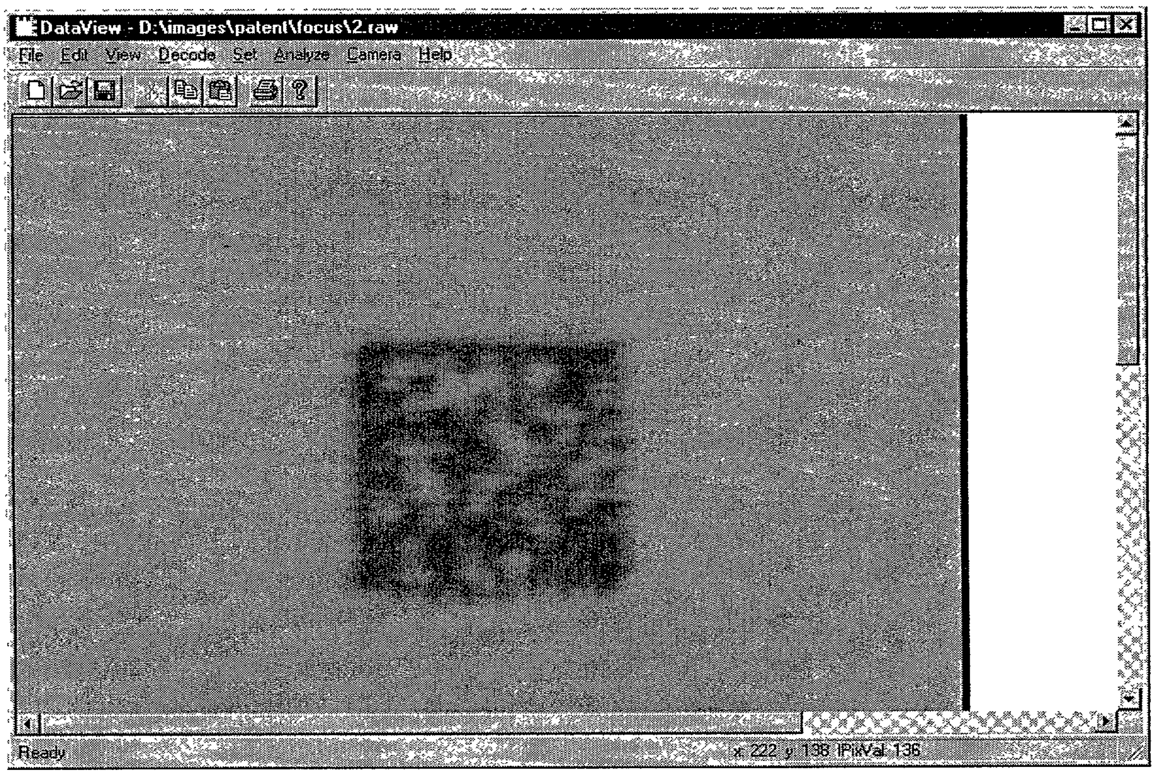


FIG. 6g

P8 image

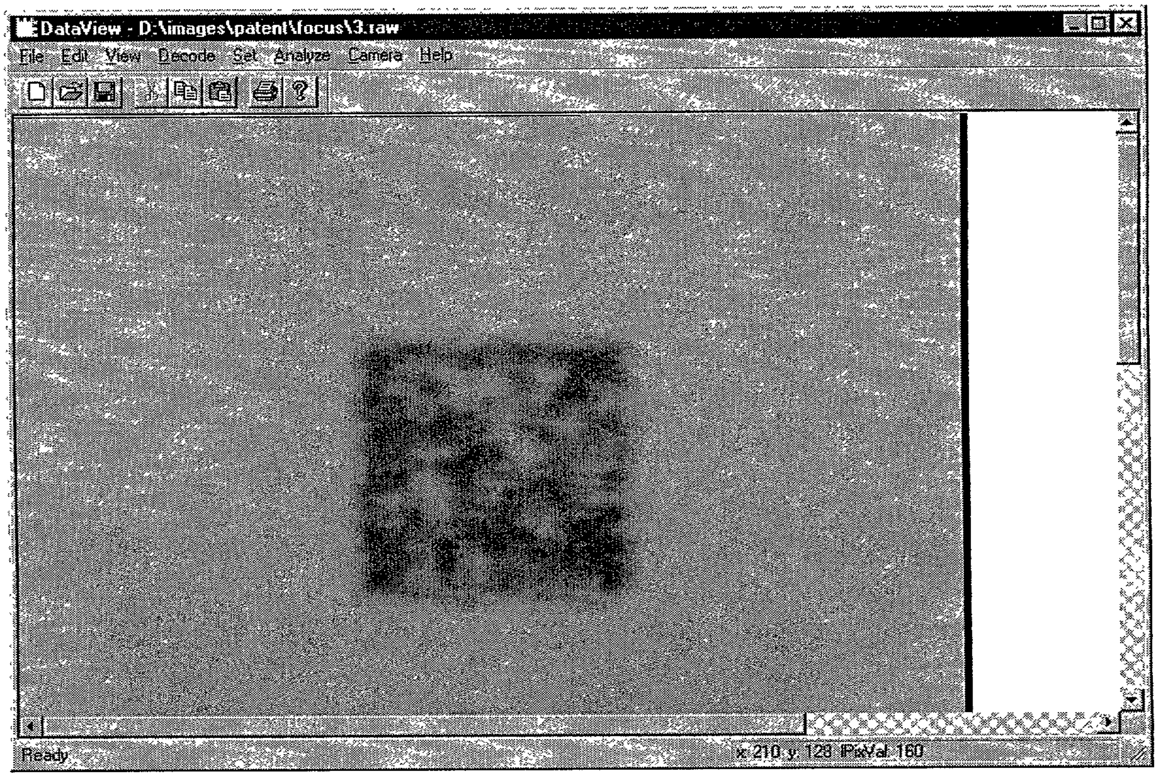


FIG. 6h

P9 image

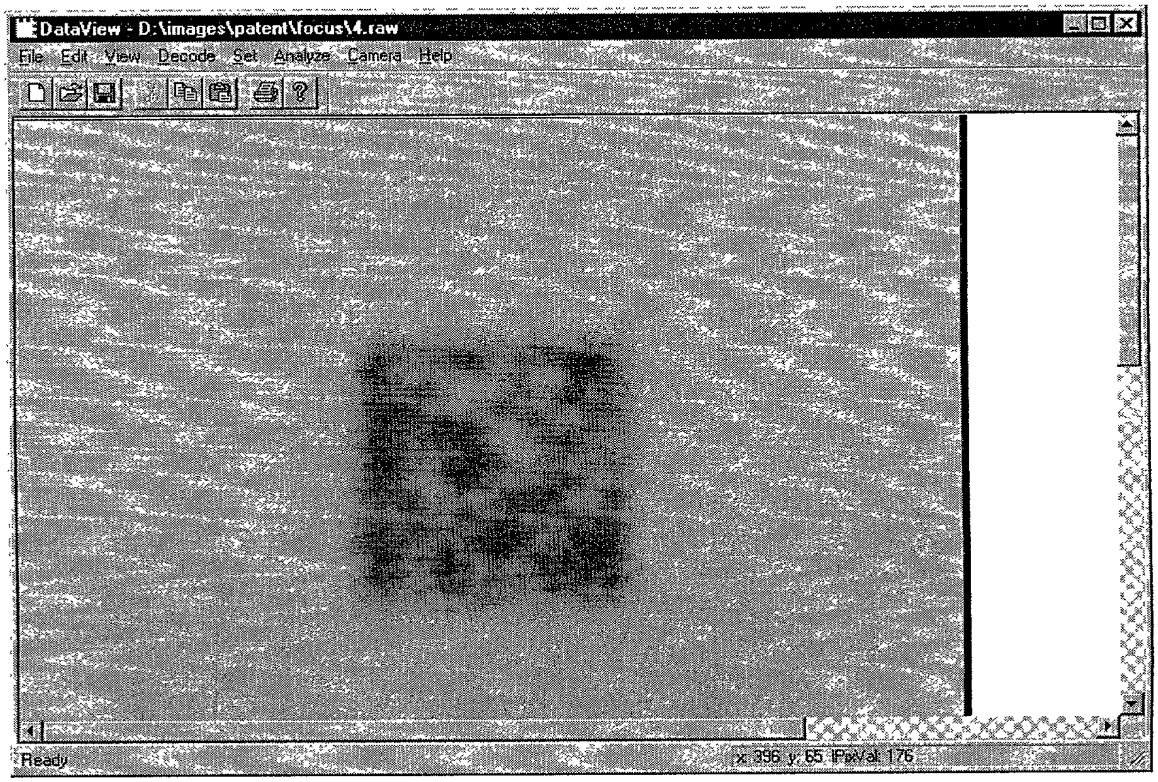


FIG. 6i

P10 image

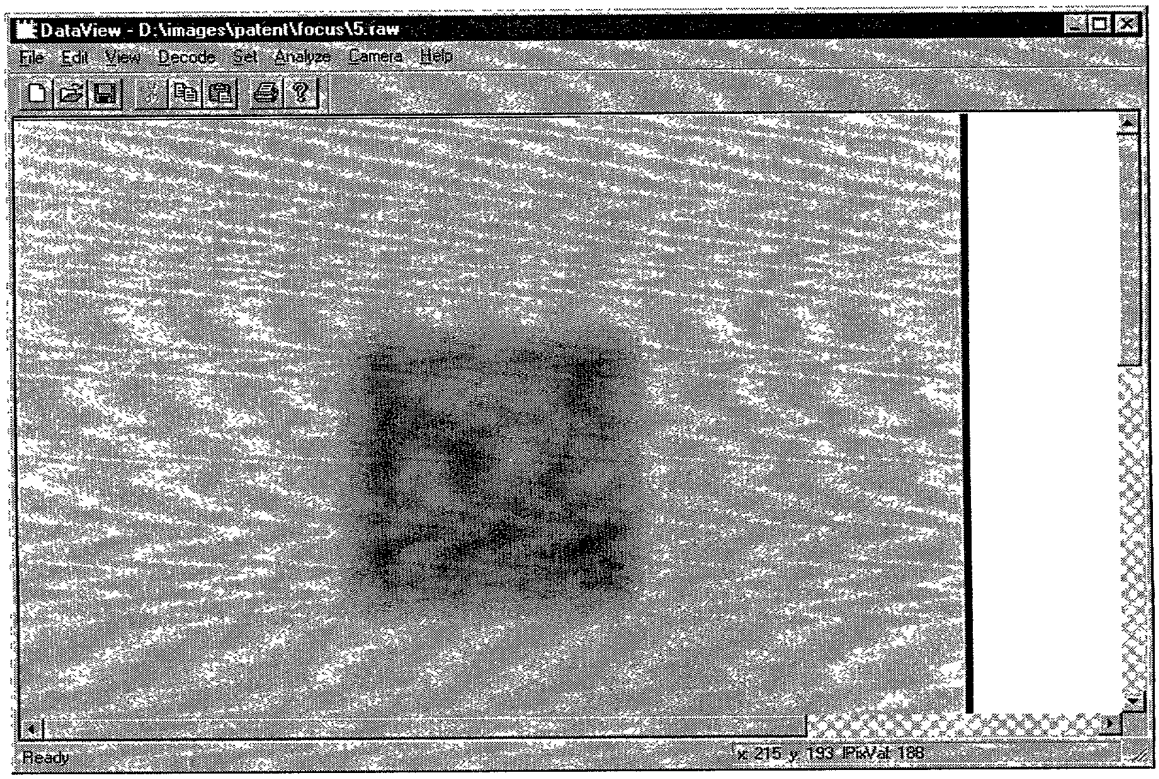


FIG. 6j

P11 image

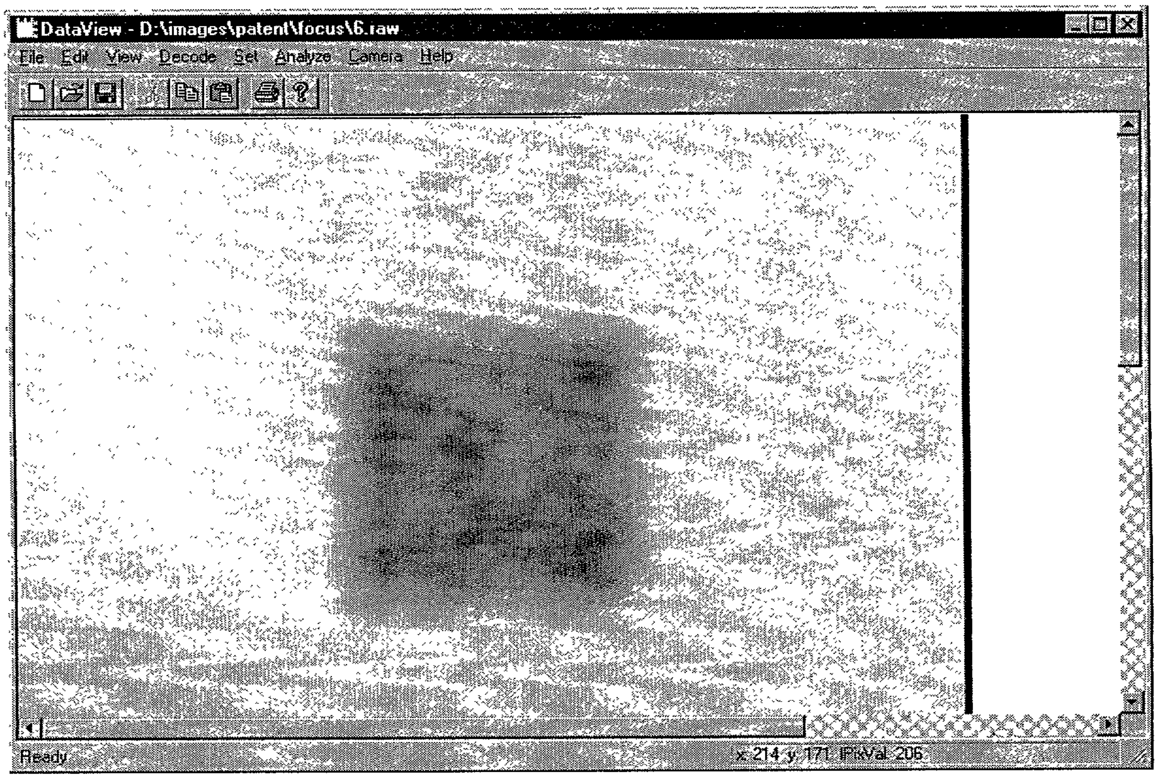
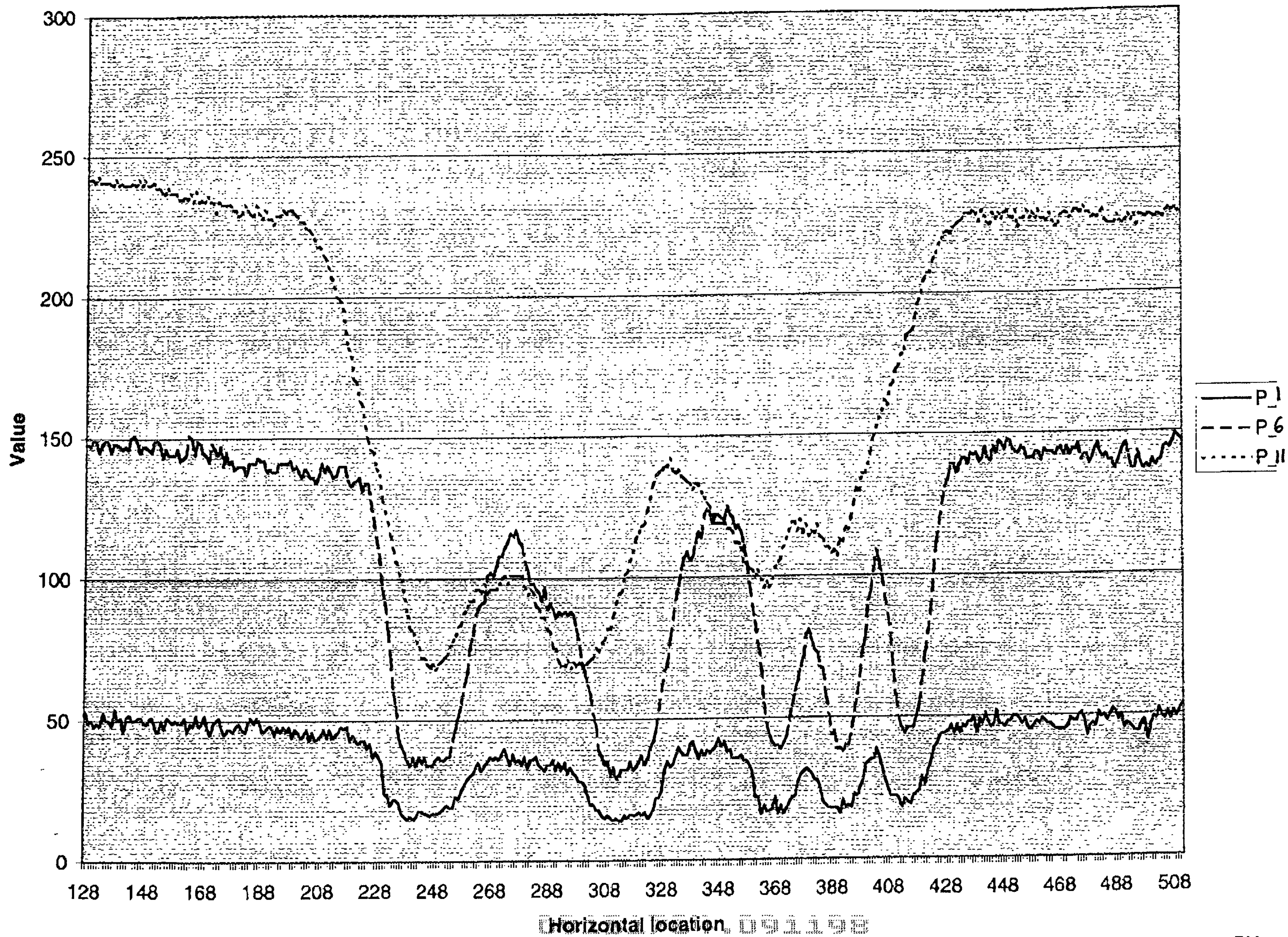


FIG. 6K

Pixel plot of line 235

FIG. 7



JHD

9/11/98 6:48 PM

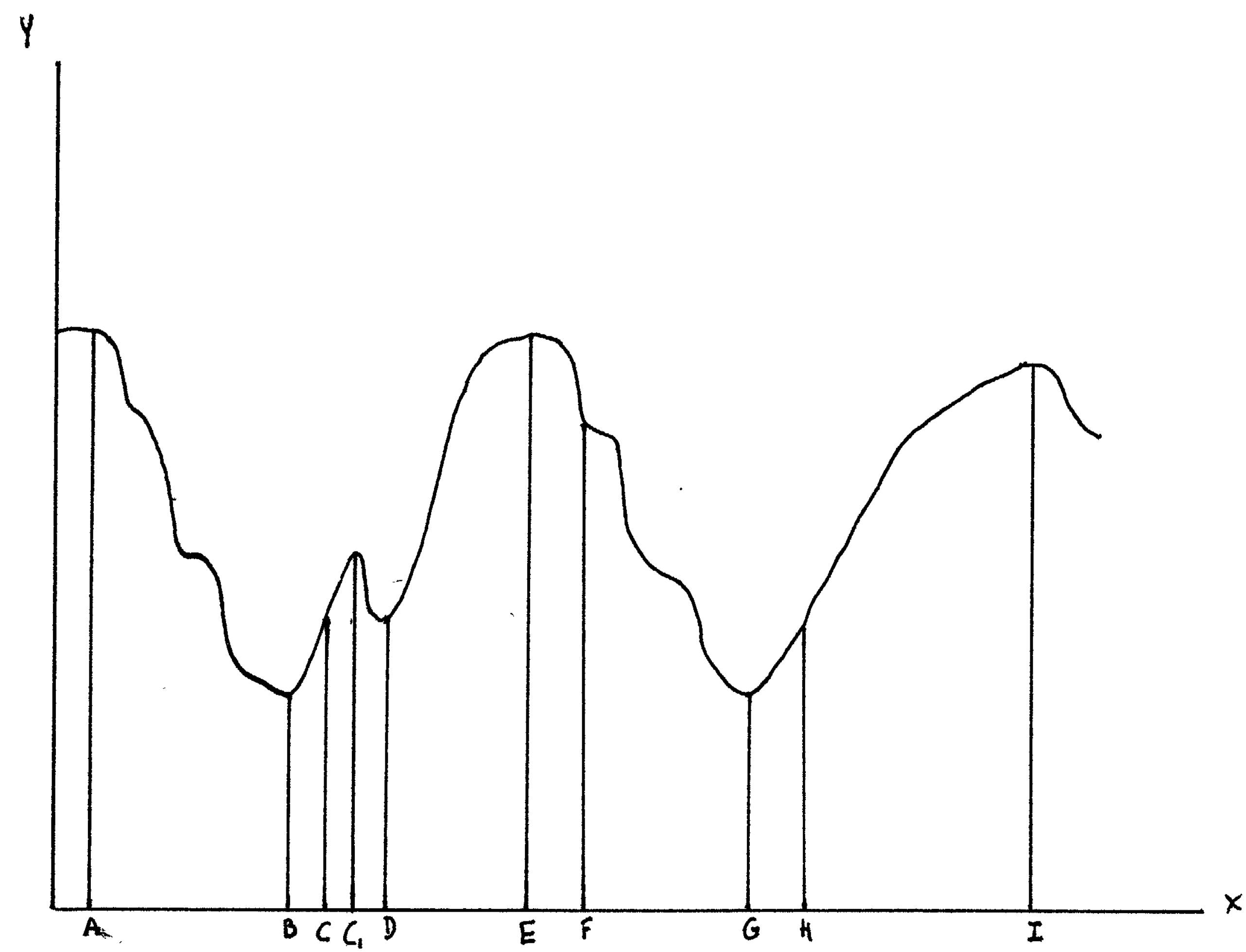


FIG. 7a

Location	P_1	P_6	P_11
128	53	148	242
129	49	147	242
130	50	149	241
131	48	149	243
132	49	145	241
133	48	148	241
134	53	149	241
135	50	149	241
136	50	145	240
137	48	148	242
138	54	148	240
139	50	147	241
140	51	146	240
141	46	147	240
142	51	146	240
143	52	150	241
144	50	151	240
145	50	149	242
146	51	145	240
147	51	147	242
148	49	147	240
149	49	146	240
150	51	145	241
151	51	149	239
152	47	149	239
153	46	148	238
154	50	143	237
155	47	146	239
156	51	144	237
157	50	144	237
158	49	144	237
159	50	146	235
160	49	142	235
161	49	143	236
162	51	144	235
163	46	151	237
164	49	150	234
165	48	144	238
166	52	149	234
167	48	148	235
168	49	145	234
169	52	144	236
170	47	142	234
171	45	148	234
172	49	146	230
173	50	144	234
174	51	147	233
175	47	140	233
176	45	145	233
177	47	141	233
178	47	142	231
179	46	139	231
180	48	140	229
181	49	140	230

FIG. 8a

Location	P_1	P_6	P_11
182	47	140	233
183	46	137	231
184	49	141	230
185	51	141	229
186	49	141	233
187	51	143	230
188	49	142	228
189	46	142	231
190	47	138	228
191	48	139	228
192	48	138	226
193	45	138	229
194	48	141	229
195	46	141	231
196	48	141	230
197	46	141	231
198	48	142	231
199	44	139	230
200	47	140	229
201	46	138	227
202	44	136	227
203	45	139	225
204	47	138	224
205	43	136	223
206	46	136	221
207	43	134	218
208	44	137	218
209	45	141	215
210	47	138	214
211	44	140	211
212	47	138	207
213	44	136	204
214	45	137	200
215	46	140	199
216	48	140	196
217	47	140	188
218	48	135	182
219	43	133	179
220	45	134	171
221	43	135	170
222	42	136	163
223	43	131	162
224	43	134	154
225	40	134	149
226	42	128	146
227	37	122	145
228	39	115	139
229	37	109	137
230	35	97	128
231	24	92	124
232	24	82	120
233	20	72	115
234	22	60	110
235	22	55	106

FIG. 8b

Location	P_1	P_6	P_11
236	21	44	102
237	17	41	100
238	16	39	93
239	15	36	87
240	16	34	82
241	15	37	81
242	16	34	78
243	18	37	76
244	18	35	72
245	17	37	72
246	17	34	70
247	16	34	69
248	17	34	70
249	17	36	68
250	17	37	70
251	18	36	71
252	19	36	72
253	20	37	73
254	19	37	76
255	19	43	78
256	23	47	80
257	22	51	83
258	25	56	84
259	27	62	88
260	29	66	90
261	30	75	92
262	31	80	92
263	33	87	96
264	35	90	96
265	32	91	95
266	34	92	98
267	35	101	95
268	37	102	96
269	36	101	96
270	37	104	96
271	36	108	98
272	38	108	100
273	40	111	101
274	37	113	98
275	34	116	101
276	38	115	101
277	35	117	101
278	36	113	101
279	34	112	101
280	37	106	97
281	33	103	94
282	36	98	96
283	36	98	95
284	37	96	90
285	34	95	89
286	33	92	86
287	32	97	86
288	34	89	82
289	34	91	81

FIG. 8c

Confidential

Location	P_1	P_6	P_11
290	36	89	76
291	32	86	75
292	35	88	70
293	32	87	69
294	35	88	69
295	31	87	71
296	33	88	68
297	31	87	70
298	30	82	69
299	28	76	70
300	28	70	68
301	27	67	69
302	23	62	70
303	20	59	71
304	20	52	72
305	18	48	75
306	18	39	74
307	16	37	77
308	15	34	78
309	16	35	82
310	15	30	82
311	14	33	87
312	15	29	91
313	14	30	94
314	14	32	95
315	16	32	101
316	15	32	102
317	16	35	106
318	16	32	109
319	16	33	114
320	17	35	116
321	16	37	118
322	17	34	119
323	15	36	124
324	16	40	128
325	18	42	133
326	22	46	136
327	22	53	137
328	25	60	138
329	32	67	139
330	35	69	139
331	33	78	142
332	34	85	138
333	37	92	137
334	40	97	138
335	38	103	136
336	37	107	135
337	37	109	134
338	41	106	133
339	42	107	131
340	39	112	133
341	36	116	133
342	39	114	130
343	37	122	128

FIG. 8d

Confidential

Location	P_1	P_6	P_11
344	39	124	126
345	38	123	125
346	39	119	122
347	40	122	119
348	43	122	119
349	40	121	119
350	42	120	119
351	38	125	117
352	39	122	117
353	36	121	116
354	36	117	112
355	36	118	112
356	37	116	110
357	35	111	105
358	35	105	105
359	33	97	103
360	31	90	102
361	22	84	100
362	22	76	102
363	16	68	99
364	19	55	96
365	17	48	98
366	17	44	96
367	18	41	99
368	22	40	103
369	16	40	105
370	19	39	106
371	16	41	110
372	18	43	113
373	20	49	116
374	22	54	119
375	22	59	119
376	27	63	116
377	30	68	120
378	31	71	115
379	32	79	118
380	31	81	114
381	30	77	116
382	28	74	115
383	28	73	118
384	25	68	114
385	20	67	113
386	19	58	110
387	18	51	110
388	18	44	108
389	18	45	109
390	18	39	107
391	16	39	113
392	21	38	112
393	18	40	117
394	19	40	116
395	18	46	121
396	23	52	126
397	22	58	131

FIG. 8e

Location	P_1	P_6	P_11
398	25	64	130
399	27	74	136
400	33	78	136
401	34	91	139
402	35	94	144
403	35	102	149
404	39	109	152
405	36	105	155
406	32	100	158
407	28	93	162
408	25	86	160
409	22	79	167
410	22	66	168
411	22	57	173
412	21	49	174
413	18	46	178
414	21	44	180
415	20	46	185
416	19	46	186
417	22	46	187
418	23	50	192
419	24	54	197
420	29	62	200
421	26	72	205
422	31	79	207
423	34	87	207
424	39	101	212
425	40	111	214
426	43	118	217
427	44	125	219
428	44	131	221
429	45	134	222
430	47	139	221
431	44	139	223
432	47	136	224
433	44	139	225
434	47	141	226
435	46	141	228
436	48	139	228
437	48	143	228
438	50	142	229
439	44	143	228
440	49	140	225
441	47	141	229
442	51	145	227
443	48	141	225
444	46	140	224
445	47	145	228
446	52	143	226
447	47	147	228
448	47	146	226
449	46	144	228
450	48	148	229
451	48	147	227

FIG. 8f

Location	P_1	P_6	P_11
452	50	144	226
453	50	143	229
454	49	143	223
455	47	145	226
456	49	144	226
457	46	141	229
458	45	141	226
459	46	141	228
460	48	143	226
461	47	143	229
462	49	140	226
463	48	144	226
464	47	143	225
465	47	143	228
466	46	143	225
467	45	142	223
468	45	144	224
469	45	145	227
470	45	142	228
471	46	145	228
472	49	142	226
473	48	144	228
474	48	144	229
475	50	146	229
476	51	140	228
477	48	142	230
478	43	142	228
479	46	139	228
480	47	141	226
481	46	144	227
482	51	146	226
483	49	142	228
484	50	141	229
485	48	142	225
486	50	140	224
487	52	140	224
488	51	137	224
489	48	139	227
490	50	142	225
491	45	145	224
492	47	146	225
493	46	141	227
494	45	137	225
495	44	137	227
496	44	143	223
497	47	139	227
498	48	137	227
499	41	138	226
500	46	137	227
501	49	140	227
502	48	138	226
503	52	139	227
504	49	140	227
505	48	144	226

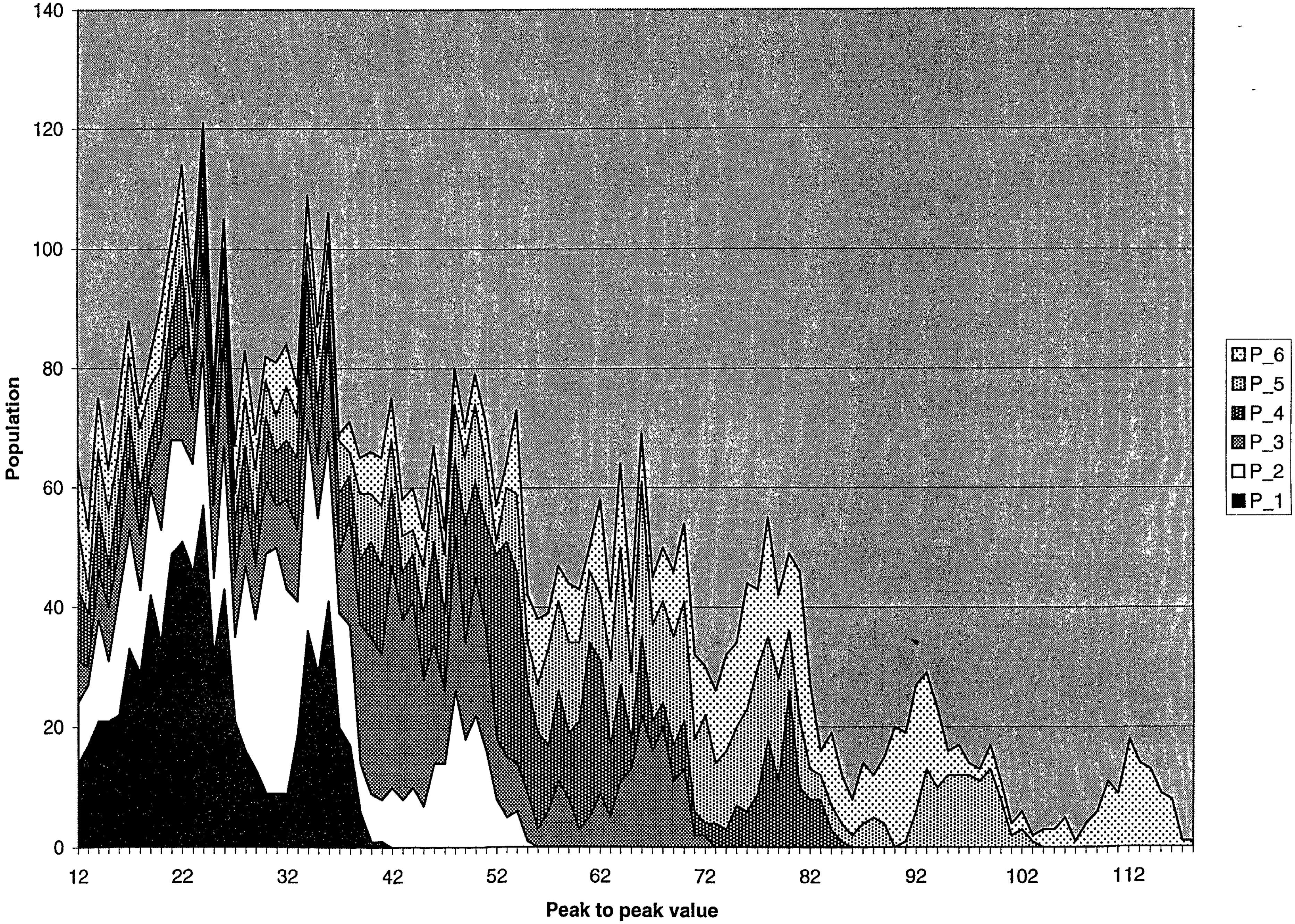
FIG. 8g

507	48	144	229
508	51	146	228
509	49	149	229
510	51	148	228
511	53	147	227

FIG. 8h

Edge Histograms

FIG. 9



Delta pk.	P_1	P_2	P_3	P_4	P_5	P_6
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	14	10	7	12	10	11
13	17	10	3	9	4	10
14	21	17	8	10	10	9
15	21	10	9	7	9	7
16	22	20	8	9	7	9
17	33	20	12	7	10	6
18	29	14	9	8	10	4
19	42	18	3	5	9	5
20	34	19	15	7	5	10
21	49	19	13	7	7	6
22	51	17	16	13	9	8
23	46	18	9	6	8	5
24	57	26	16	11	6	5
25	32	13	12	10	7	3
26	43	24	18	9	6	5
27	21	14	10	9	5	8
28	16	31	11	9	8	8
29	13	25	9	7	9	6
30	9	40	12	11	6	4
31	9	41	7	9	6	9
32	9	34	15	10	9	7
33	19	22	12	12	7	5
34	36	34	12	14	5	8
35	29	26	9	10	8	5
36	41	27	18	7	8	5
37	20	19	10	10	9	1
38	17	20	18	7	4	5
39	6	8	23	11	11	6
40	1	8	26	16	8	7
41	1	7	24	15	10	8
42	0	10	37	13	8	7
43	0	8	30	8	6	6
44	0	10	31	8	4	7
45	0	7	21	11	8	6
46	0	14	20	17	11	5
47	0	14	12	13	10	4
48	0	26	26	13	9	6
49	0	18	16	20	11	5
50	0	22	23	16	13	5
51	0	16	20	18	10	7
52	0	8	10	31	2	6
53	0	5	10	36	9	4

FIG. 10a

Delta pk.	P_1	P_2	P_3	P_4	P_5	P_6
54	0	6	8	32	13	14
55	0	1	8	18	7	8
56	0	0	3	16	8	11
57	0	0	6	11	16	6
58	0	0	11	15	15	6
59	0	0	8	11	15	10
60	0	0	3	18	13	9
61	0	0	5	29	12	4
62	0	0	9	22	11	16
63	0	0	5	12	14	10
64	0	0	11	16	23	14
65	0	0	13	5	11	12
66	0	0	22	13	26	8
67	0	0	16	5	16	8
68	0	0	20	4	17	9
69	0	0	11	6	18	11
70	0	0	13	8	20	13
71	0	0	2	4	12	14
72	0	0	2	2	18	8
73	0	0	0	4	10	12
74	0	0	0	3	13	16
75	0	0	0	7	13	14
76	0	0	0	6	17	21
77	0	0	0	9	21	13
78	0	0	0	18	17	20
79	0	0	0	11	17	14
80	0	0	0	26	10	13
81	0	0	0	10	11	25
82	0	0	0	8	5	14
83	0	0	0	8	4	4
84	0	0	0	3	4	12
85	0	0	0	1	3	8
86	0	0	0	0	2	6
87	0	0	0	0	4	10
88	0	0	0	0	5	7
89	0	0	0	0	4	11
90	0	0	0	0	0	20
91	0	0	0	0	1	18
92	0	0	0	0	6	21
93	0	0	0	0	13	16
94	0	0	0	0	10	13
95	0	0	0	0	12	4
96	0	0	0	0	12	5
97	0	0	0	0	12	2
98	0	0	0	0	11	2
99	0	0	0	0	13	4
100	0	0	0	0	8	3
101	0	0	0	0	2	2
102	0	0	0	0	3	3
103	0	0	0	0	1	1
104	0	0	0	0	0	3
105	0	0	0	0	0	3
106	0	0	0	0	0	5
107	0	0	0	0	0	1

FIG 10b

Delta pk.	P_1	P_2	P_3	P_4	P_5	P_6
108	0	0	0	0	0	4
109	0	0	0	0	0	6
110	0	0	0	0	0	11
111	0	0	0	0	0	9
112	0	0	0	0	0	18
113	0	0	0	0	0	14
114	0	0	0	0	0	13
115	0	0	0	0	0	9
116	0	0	0	0	0	8
117	0	0	0	0	0	1
118	0	0	0	0	0	1
119	0	0	0	0	0	0
120	0	0	0	0	0	0
121	0	0	0	0	0	0
122	0	0	0	0	0	0
123	0	0	0	0	0	0
124	0	0	0	0	0	0
125	0	0	0	0	0	0
126	0	0	0	0	0	0
127	0	0	0	0	0	0
128	0	0	0	0	0	0
129	0	0	0	0	0	0
130	0	0	0	0	0	0
131	0	0	0	0	0	0
132	0	0	0	0	0	0
133	0	0	0	0	0	0
134	0	0	0	0	0	0
135	0	0	0	0	0	0
136	0	0	0	0	0	0
137	0	0	0	0	0	0
138	0	0	0	0	0	0
139	0	0	0	0	0	0
140	0	0	0	0	0	0
141	0	0	0	0	0	0
142	0	0	0	0	0	0
143	0	0	0	0	0	0
144	0	0	0	0	0	0
145	0	0	0	0	0	0
146	0	0	0	0	0	0
147	0	0	0	0	0	0
148	0	0	0	0	0	0
149	0	0	0	0	0	0
150	0	0	0	0	0	0
151	0	0	0	0	0	0
152	0	0	0	0	0	0
153	0	0	0	0	0	0
154	0	0	0	0	0	0
155	0	0	0	0	0	0
156	0	0	0	0	0	0
157	0	0	0	0	0	0
158	0	0	0	0	0	0
159	0	0	0	0	0	0
160	0	0	0	0	0	0
161	0	0	0	0	0	0

FIG. 10c

Delta pk.	P_1	P_2	P_3	P_4	P_5	P_6
162	0	0	0	0	0	0
163	0	0	0	0	0	0
164	0	0	0	0	0	0
165	0	0	0	0	0	0
166	0	0	0	0	0	0
167	0	0	0	0	0	0
168	0	0	0	0	0	0
169	0	0	0	0	0	0
170	0	0	0	0	0	0
171	0	0	0	0	0	0
172	0	0	0	0	0	0
173	0	0	0	0	0	0
174	0	0	0	0	0	0
175	0	0	0	0	0	0
176	0	0	0	0	0	0
177	0	0	0	0	0	0
178	0	0	0	0	0	0
179	0	0	0	0	0	0
180	0	0	0	0	0	0
181	0	0	0	0	0	0
182	0	0	0	0	0	0
183	0	0	0	0	0	0
184	0	0	0	0	0	0
185	0	0	0	0	0	0
186	0	0	0	0	0	0
187	0	0	0	0	0	0
188	0	0	0	0	0	0
189	0	0	0	0	0	0
190	0	0	0	0	0	0
191	0	0	0	0	0	0
192	0	0	0	0	0	0
193	0	0	0	0	0	0
194	0	0	0	0	0	0
195	0	0	0	0	0	0
196	0	0	0	0	0	0
197	0	0	0	0	0	0
198	0	0	0	0	0	0
199	0	0	0	0	0	0
200	0	0	0	0	0	0
201	0	0	0	0	0	0
202	0	0	0	0	0	0
203	0	0	0	0	0	0
204	0	0	0	0	0	0
205	0	0	0	0	0	0
206	0	0	0	0	0	0
207	0	0	0	0	0	0
208	0	0	0	0	0	0
209	0	0	0	0	0	0
210	0	0	0	0	0	0
211	0	0	0	0	0	0
212	0	0	0	0	0	0
213	0	0	0	0	0	0
214	0	0	0	0	0	0
215	0	0	0	0	0	0

FIG. 10d

Delta pk.	P_1	P_2	P_3	P_4	P_5	P_6
216	0	0	0	0	0	0
217	0	0	0	0	0	0
218	0	0	0	0	0	0
219	0	0	0	0	0	0
220	0	0	0	0	0	0
221	0	0	0	0	0	0
222	0	0	0	0	0	0
223	0	0	0	0	0	0
224	0	0	0	0	0	0
225	0	0	0	0	0	0
226	0	0	0	0	0	0
227	0	0	0	0	0	0
228	0	0	0	0	0	0
229	0	0	0	0	0	0
230	0	0	0	0	0	0
231	0	0	0	0	0	0
232	0	0	0	0	0	0
233	0	0	0	0	0	0
234	0	0	0	0	0	0
235	0	0	0	0	0	0
236	0	0	0	0	0	0
237	0	0	0	0	0	0
238	0	0	0	0	0	0
239	0	0	0	0	0	0
240	0	0	0	0	0	0
241	0	0	0	0	0	0
242	0	0	0	0	0	0
243	0	0	0	0	0	0
244	0	0	0	0	0	0
245	0	0	0	0	0	0
246	0	0	0	0	0	0
247	0	0	0	0	0	0
248	0	0	0	0	0	0
249	0	0	0	0	0	0
250	0	0	0	0	0	0
251	0	0	0	0	0	0
252	0	0	0	0	0	0
253	0	0	0	0	0	0
254	0	0	0	0	0	0
255	0	0	0	0	0	0

FIG. 10e

IMAGE p6:

Entropy Score	781
Max Pixel Value	153
Min Pixel Value	30

IMAGE p7:

Entropy Score	518
Max Pixel Value	149
Min Pixel Value	30

IMAGE p8:

Entropy Score	468
Max Pixel Value	172
Min Pixel Value	34

IMAGE p9:

Entropy Score	464
Max Pixel Value	189
Min Pixel Value	39

IMAGE p10:

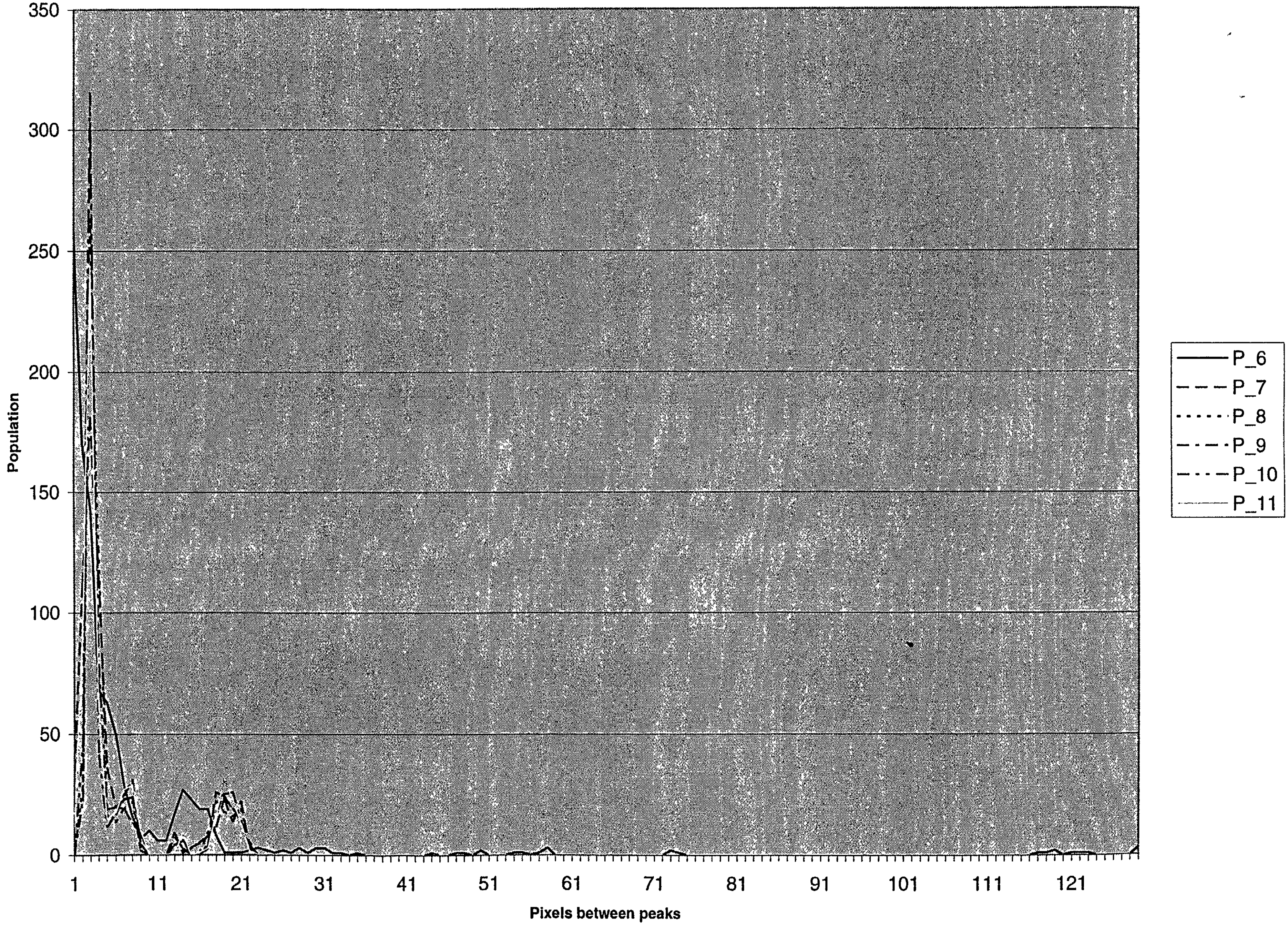
Entropy Score	455
Max Pixel Value	212
Min Pixel Value	46

IMAGE p11:

Entropy Score	461
Max Pixel Value	243
Min Pixel Value	66

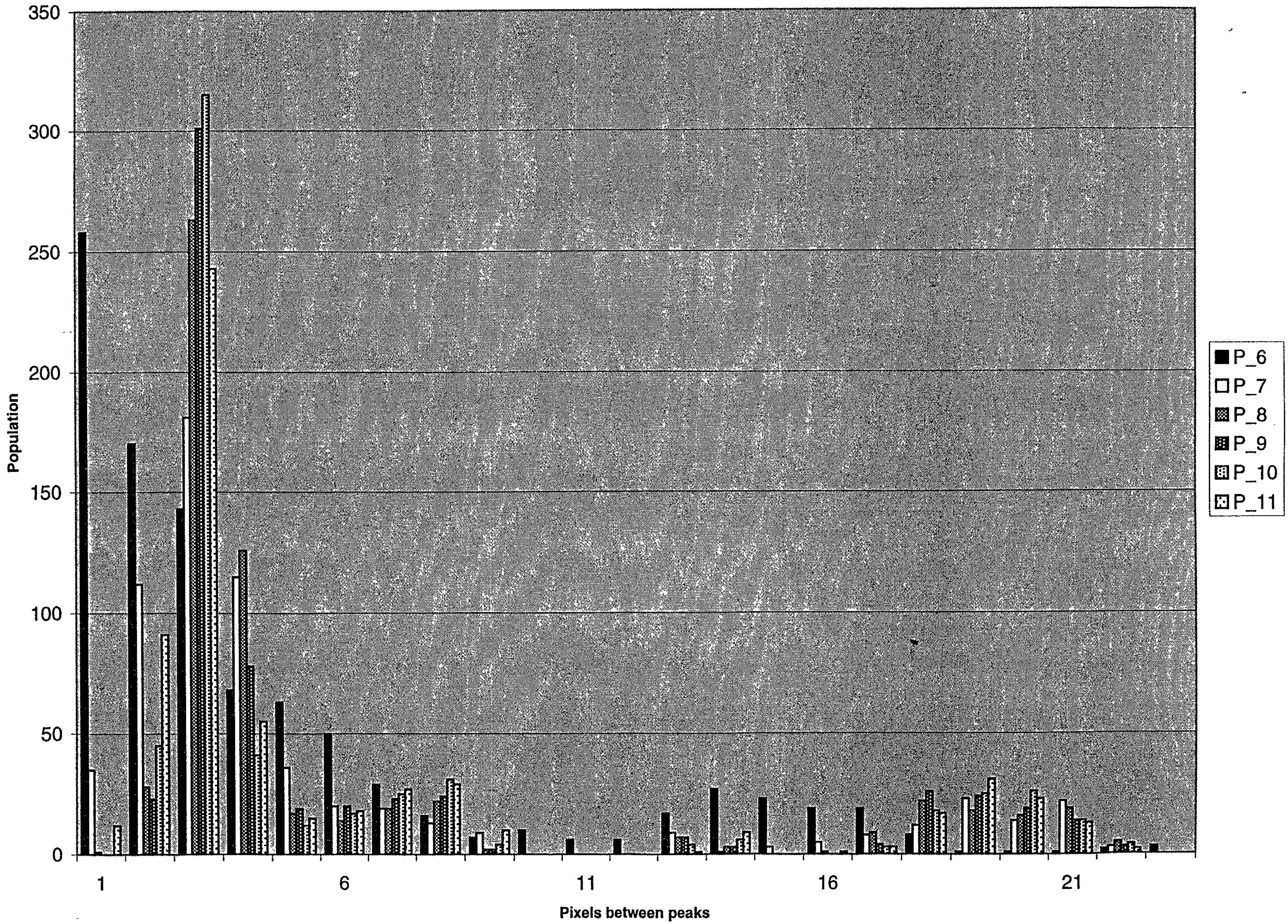
Fig. 11

Frequency Histogram FIG. 12a



Frequency Histogram Zoom

FIG. 12b



Delta pix.	P_6	P_7	P_8	P_9	P_10	P_11
0	0	0	0	0	0	0
1	258	35	1	0	0	12
2	170	112	28	23	45	91
3	143	181	263	301	315	243
4	68	115	126	78	41	55
5	63	36	17	19	12	15
6	50	20	14	20	17	18
7	29	19	19	23	25	27
8	16	13	22	24	31	29
9	7	9	2	2	4	10
10	10	0	0	0	0	0
11	6	0	0	0	0	0
12	6	0	0	0	0	0
13	17	9	7	7	4	1
14	27	1	3	3	6	9
15	23	3	0	0	0	0
16	19	5	1	0	0	1
17	19	8	9	4	3	3
18	8	12	22	26	18	17
19	1	23	18	24	25	31
20	1	14	16	19	26	23
21	1	22	19	14	14	13
22	2	3	5	3	4	2
23	3	0	0	0	0	0
24	2	0	0	0	0	0
25	1	0	0	0	0	0
26	2	0	0	0	0	0
27	1	0	0	0	0	0
28	3	0	0	0	0	0
29	1	0	0	0	0	0
30	3	0	0	0	0	0
31	3	0	0	0	0	0
32	1	0	0	0	0	0
33	1	0	0	0	0	0
34	0	0	0	0	0	0
35	1	0	0	0	0	0
36	0	0	0	0	0	0
37	0	0	0	0	0	0
38	0	0	0	0	0	0
39	0	0	0	0	0	0
40	0	0	0	0	0	0
41	0	0	0	0	0	0
42	0	0	0	0	0	0
43	0	0	0	0	0	0
44	1	0	0	0	0	0
45	0	0	0	0	0	0
46	0	0	0	0	0	0
47	1	0	0	0	0	0
48	1	0	0	0	0	0
49	0	0	0	0	0	0
50	2	0	0	0	0	0
51	0	0	0	0	0	0
52	0	0	0	0	0	0
53	0	0	0	0	0	0

FIG. 13a

Delta pix.	P_6	P_7	P_8	P_9	P_10	P_11
54	1	0	0	0	0	0
55	1	0	0	0	0	0
56	0	0	0	0	0	0
57	1	0	0	0	0	0
58	3	0	0	0	0	0
59	0	0	0	0	0	0
60	0	0	0	0	0	0
61	0	0	0	0	0	0
62	0	0	0	0	0	0
63	0	0	0	0	0	0
64	0	0	0	0	0	0
65	0	0	0	0	0	0
66	0	0	0	0	0	0
67	0	0	0	0	0	0
68	0	0	0	0	0	0
69	0	0	0	0	0	0
70	0	0	0	0	0	0
71	0	0	0	0	0	0
72	0	0	0	0	0	0
73	2	0	0	0	0	0
74	1	0	0	0	0	0
75	0	0	0	0	0	0
76	0	0	0	0	0	0
77	0	0	0	0	0	0
78	0	0	0	0	0	0
79	0	0	0	0	0	0
80	0	0	0	0	0	0
81	0	0	0	0	0	0
82	0	0	0	0	0	0
83	0	0	0	0	0	0
84	0	0	0	0	0	0
85	0	0	0	0	0	0
86	0	0	0	0	0	0
87	0	0	0	0	0	0
88	0	0	0	0	0	0
89	0	0	0	0	0	0
90	0	0	0	0	0	0
91	0	0	0	0	0	0
92	0	0	0	0	0	0
93	0	0	0	0	0	0
94	0	0	0	0	0	0
95	0	0	0	0	0	0
96	0	0	0	0	0	0
97	0	0	0	0	0	0
98	0	0	0	0	0	0
99	0	0	0	0	0	0
100	0	0	0	0	0	0
101	0	0	0	0	0	0
102	0	0	0	0	0	0
103	0	0	0	0	0	0
104	0	0	0	0	0	0
105	0	0	0	0	0	0
106	0	0	0	0	0	0
107	0	0	0	0	0	0

FIG. 13b

Delta pix.	P_6	P_7	P_8	P_9	P_10	P_11
108	0	0	0	0	0	0
109	0	0	0	0	0	0
110	0	0	0	0	0	0
111	0	0	0	0	0	0
112	0	0	0	0	0	0
113	0	0	0	0	0	0
114	0	0	0	0	0	0
115	0	0	0	0	0	0
116	0	0	0	0	0	0
117	1	0	0	0	0	0
118	1	0	0	0	0	0
119	2	0	0	0	0	0
120	0	0	0	0	0	0
121	1	0	0	0	0	0
122	1	0	0	0	0	0
123	1	0	0	0	0	0
124	0	0	0	0	0	0
125	0	0	0	0	0	0
126	0	0	0	0	0	0
127	0	0	0	0	0	0
128	0	0	0	0	0	0
129	3	0	0	0	0	0
130	0	0	0	0	0	0
131	0	0	0	0	0	0
132	0	0	0	0	0	0
133	0	0	0	0	0	0
134	0	0	0	0	0	0
135	0	0	0	0	0	0
136	0	0	0	0	0	0
137	0	0	0	0	0	0
138	0	0	0	0	0	0
139	0	0	0	0	0	0
140	0	0	0	0	0	0
141	0	0	0	0	0	0
142	0	0	0	0	0	0
143	0	0	0	0	0	0
144	0	0	0	0	0	0
145	0	0	0	0	0	0
146	0	0	0	0	0	0
147	0	0	0	0	0	0
148	0	0	0	0	0	0
149	0	0	0	0	0	0
150	0	0	0	0	0	0
151	0	0	0	0	0	0
152	0	0	0	0	0	0
153	0	0	0	0	0	0
154	0	0	0	0	0	0
155	0	0	0	0	0	0
156	0	0	0	0	0	0
157	0	0	0	0	0	0
158	0	0	0	0	0	0
159	0	0	0	0	0	0
160	0	0	0	0	0	0
161	0	0	0	0	0	0

FIG. 13c

Delta pix.	P_6	P_7	P_8	P_9	P_10	P_11
162	0	0	0	0	0	0
163	0	0	0	0	0	0
164	0	0	0	0	0	0
165	0	0	0	0	0	0
166	0	0	0	0	0	0
167	0	0	0	0	0	0
168	0	0	0	0	0	0
169	0	0	0	0	0	0
170	0	0	0	0	0	0
171	0	0	0	0	0	0
172	0	0	0	0	0	0
173	0	0	0	0	0	0
174	0	0	0	0	0	0
175	0	0	0	0	0	0
176	0	0	0	0	0	0
177	0	0	0	0	0	0
178	0	0	0	0	0	0
179	0	0	0	0	0	0
180	0	0	0	0	0	0
181	0	0	0	0	0	0
182	0	0	0	0	0	0
183	0	0	0	0	0	0
184	0	0	0	0	0	0
185	0	0	0	0	0	0
186	0	0	0	0	0	0
187	0	0	0	0	0	0
188	0	0	0	0	0	0
189	0	0	0	0	0	0
190	0	0	0	0	0	0
191	0	0	0	0	0	0
192	0	0	0	0	0	0
193	0	0	0	0	0	0
194	0	0	0	0	0	0
195	0	0	0	0	0	0
196	0	0	0	0	0	0
197	0	0	0	0	0	0
198	0	0	0	0	0	0
199	0	0	0	0	0	0
200	0	0	0	0	0	0
201	0	0	0	0	0	0
202	0	0	0	0	0	0
203	0	0	0	0	0	0
204	0	0	0	0	0	0
205	0	0	0	0	0	0
206	0	0	0	0	0	0
207	0	0	0	0	0	0
208	0	0	0	0	0	0
209	0	0	0	0	0	0
210	0	0	0	0	0	0
211	0	0	0	0	0	0
212	0	0	0	0	0	0
213	0	0	0	0	0	0
214	0	0	0	0	0	0
215	0	0	0	0	0	0

FIG. 13d

Delta pix.	P_6	P_7	P_8	P_9	P_10	P_11
216	0	0	0	0	0	0
217	0	0	0	0	0	0
218	0	0	0	0	0	0
219	0	0	0	0	0	0
220	0	0	0	0	0	0
221	0	0	0	0	0	0
222	0	0	0	0	0	0
223	0	0	0	0	0	0
224	0	0	0	0	0	0
225	0	0	0	0	0	0
226	0	0	0	0	0	0
227	0	0	0	0	0	0
228	0	0	0	0	0	0
229	0	0	0	0	0	0
230	0	0	0	0	0	0
231	0	0	0	0	0	0
232	0	0	0	0	0	0
233	0	0	0	0	0	0
234	0	0	0	0	0	0
235	0	0	0	0	0	0
236	0	0	0	0	0	0
237	0	0	0	0	0	0
238	0	0	0	0	0	0
239	0	0	0	0	0	0
240	0	0	0	0	0	0
241	0	0	0	0	0	0
242	0	0	0	0	0	0
243	0	0	0	0	0	0
244	0	0	0	0	0	0
245	0	0	0	0	0	0
246	0	0	0	0	0	0
247	0	0	0	0	0	0
248	0	0	0	0	0	0
249	0	0	0	0	0	0
250	0	0	0	0	0	0
251	0	0	0	0	0	0
252	0	0	0	0	0	0
253	0	0	0	0	0	0
254	0	0	0	0	0	0
255	0	0	0	0	0	0

FIG. 13e

FIG. 14

IMAGE p1:

Entropy Score	758
Max Pixel Value	55
Min Pixel Value	14

IMAGE p2:

Entropy Score	776
Max Pixel Value	73
Min Pixel Value	18

IMAGE p3:

Entropy Score	806
Max Pixel Value	97
Min Pixel Value	22

IMAGE p4:

Entropy Score	852
Max Pixel Value	112
Min Pixel Value	24

IMAGE p5:

Entropy Score	880
Max Pixel Value	133
Min Pixel Value	27

IMAGE p6:

Entropy Score	894
Max Pixel Value	152
Min Pixel Value	30

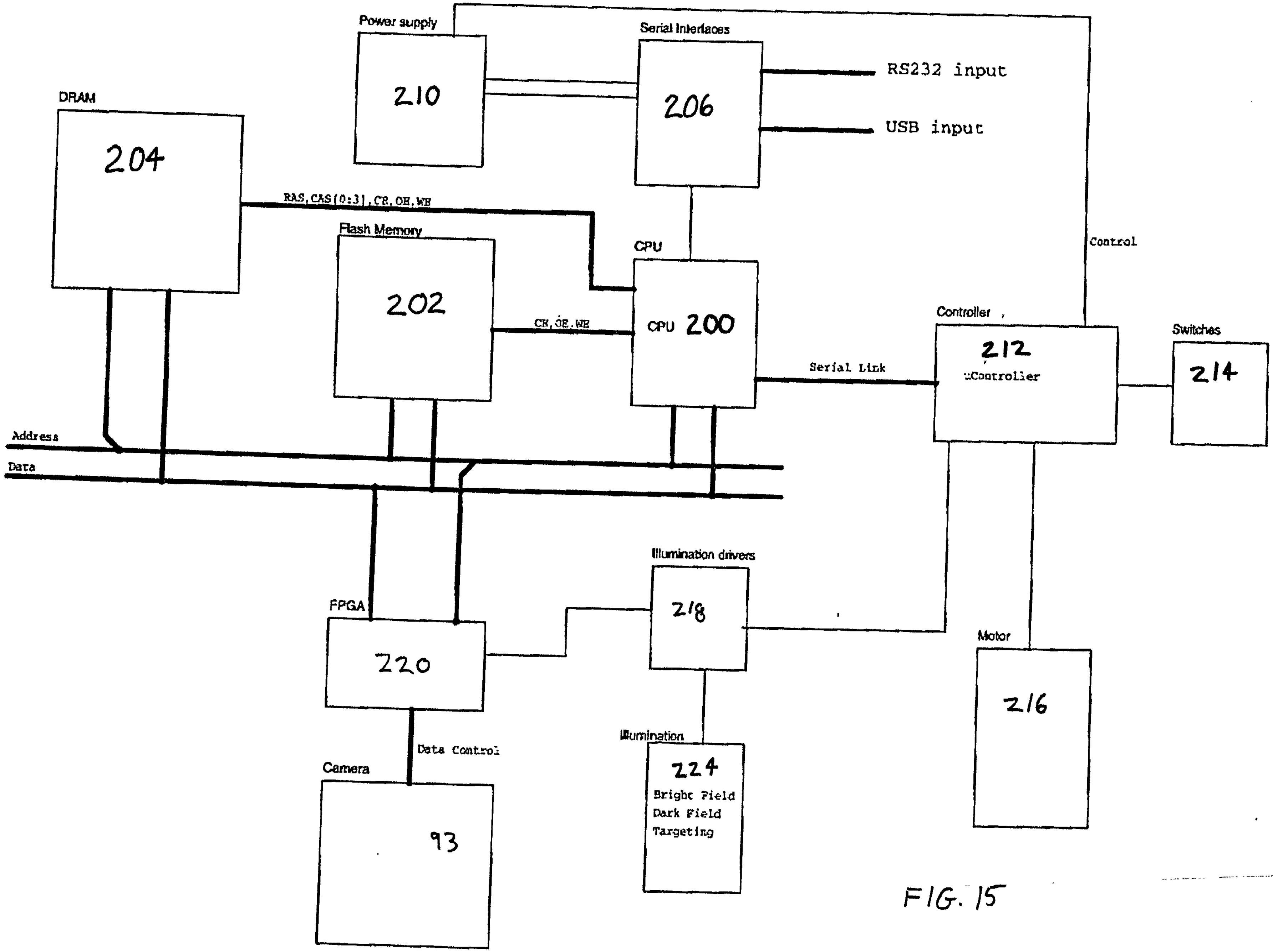

Power supply
210
Serial Interfaces
206
RS232 input
USB input
DRAM
204
RAS,CAS(0:3),CE,OE,WE
Flash Memory
202
CPU
CPU 200
CE,OE,WE
Control
Controller
212
uController
Serial Link
Switches
214
Address
Data
Illumination drivers
218
FPGA
220
Motor
216
Data Control
Camera
93
Illumination
224
Bright Field
Dark Field
Targeting

FIG. 15